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Doviak et al.

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(45) **Date of Patent: *Nov. 30, 2004**

(54) **APPARATUS AND METHOD FOR INTELLIGENT ROUTING OF DATA BETWEEN A REMOTE DEVICE AND A HOST SYSTEM**

(75) Inventors: **William Doviak**, Pottstown, PA (US); **David L. Whitmore**, Bethlehem, PA (US); **Flex Houvig**, Wayne, PA (US)

(73) Assignee: **Padcom, Inc.**, Bethlehem, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 347 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Jun. 10, 2002**

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Related U.S. Application Data

(63) Continuation of application No. 08/932,532, filed on Sep. 17, 1997, now Pat. No. 6,418,324, which is a continuation-in-part of application No. 08/456,860, filed on Jun. 1, 1995, now Pat. No. 5,717,737.

(51) **Int. Cl.**[7] **H04Q 7/20**
(52) **U.S. Cl.** **455/445**; 455/552.1
(58) **Field of Search** 455/426.1, 453, 455/454, 458, 466, 459, 552.1, 553.1, 556, 557, 445, 517; 379/114, 210, 211, 207, 214, 220, 272, 274, 279; 370/237, 238, 259, 244, 271, 310, 410, 466, 400, 401, 250

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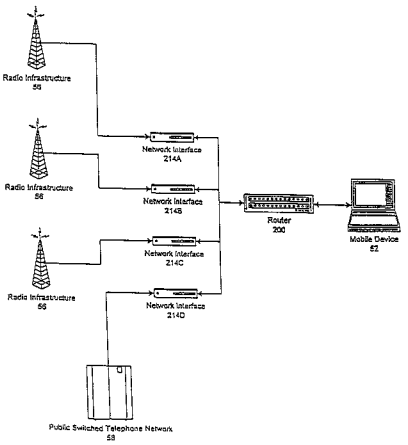
Primary Examiner—Jean Gelin
(74) *Attorney, Agent, or Firm*—Greenblum & Bernstein, P.L.C.

(57) **ABSTRACT**

An apparatus and method is provided for transparent communication between a remote or mobile device and a fixed communication host network. The apparatus and method may include a remote network controller that logically resides between the host network and the existing infrastructure(s) that are used to provide communications network contact with one or more remote devices. The remote network controller is connected to the host communication network as a protocol-appropriate communications controller so that remote devices are indistinguishable to the host network from the locally-attached devices. Each remote device may be provided with an asynchronous serial data interface to communicate with a mobile data controller. The mobile data controller, in combination with the remote network controller, provides end-to-end data communication such that incompatible protocols are transparent to the remote device and host communication network. A router may be provided which selects a communications network in accordance with user configured parameters. The router communicates over a plurality of incompatible networks and is capable of using a variety of different protocols. Switching between the plurality of incompatible networks is transparent to the remote device and host communication network.

72 Claims, 38 Drawing Sheets



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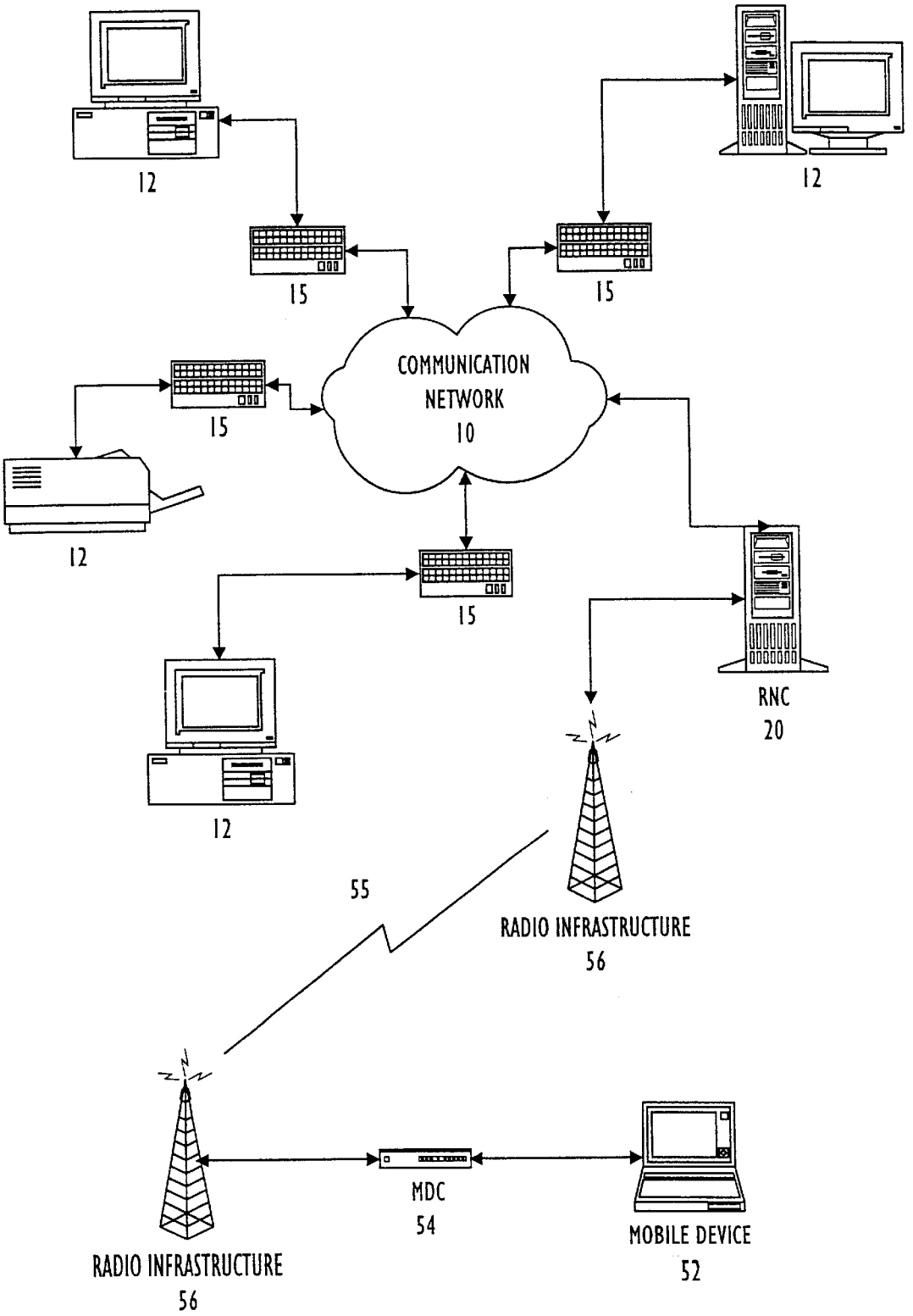

12
12
15
15
COMMUNICATION NETWORK 10
15
12
15
12
RNC 20
55
RADIO INFRASTRUCTURE 56
MDC 54
RADIO INFRASTRUCTURE 56
MOBILE DEVICE 52

FIG. 1

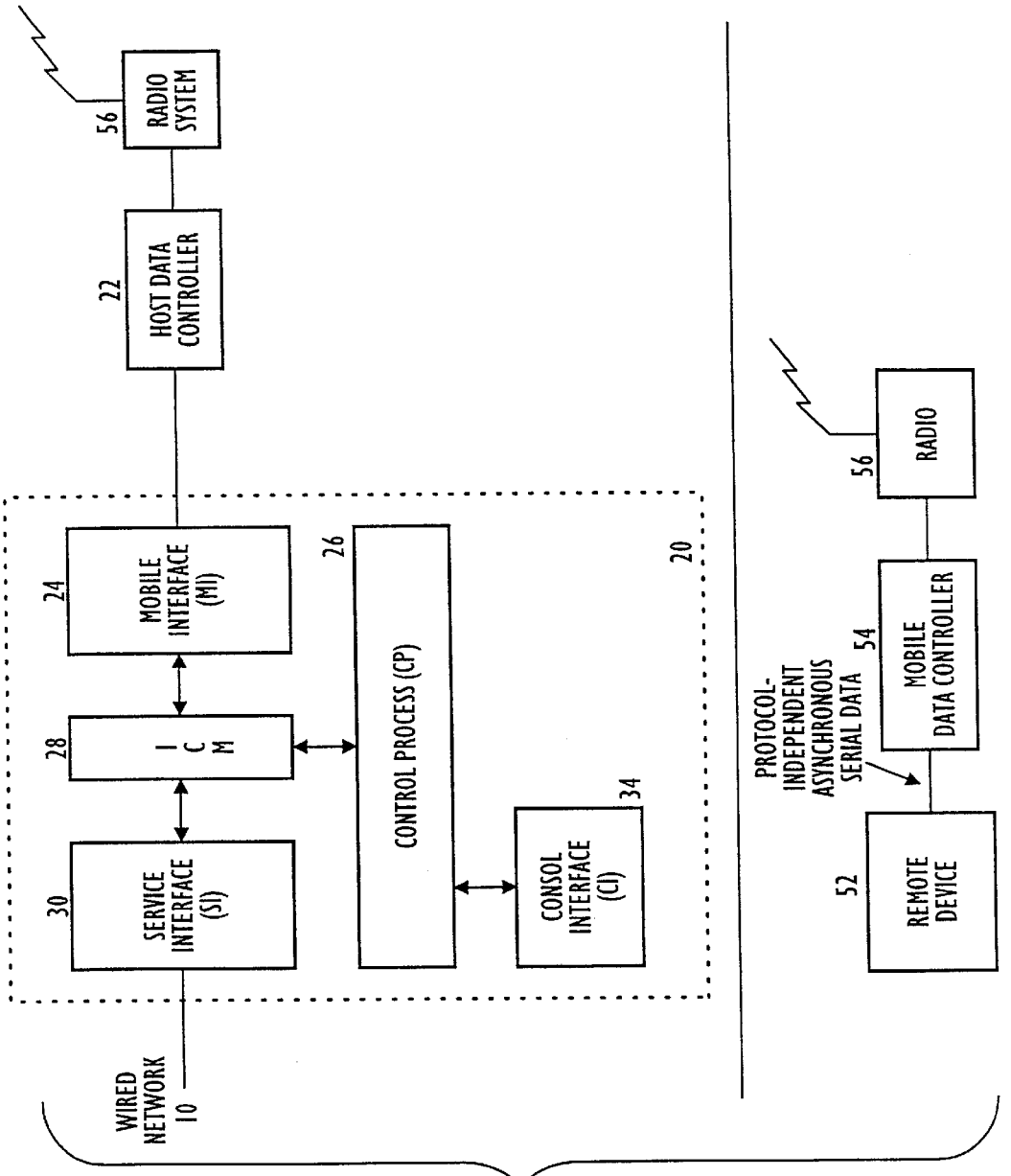

RADIO SYSTEM
56
HOST DATA CONTROLLER
22
MOBILE INTERFACE (MI)
24
I C M
28
SERVICE INTERFACE (SI)
30
CONTROL PROCESS (CP)
26
CONSOL INTERFACE (CI)
34
20
WIRED NETWORK 10
RADIO
56
MOBILE DATA CONTROLLER
54
PROTOCOL-INDEPENDENT ASYNCHRONOUS SERIAL DATA
REMOTE DEVICE
52

FIG. 2

FIG. 3

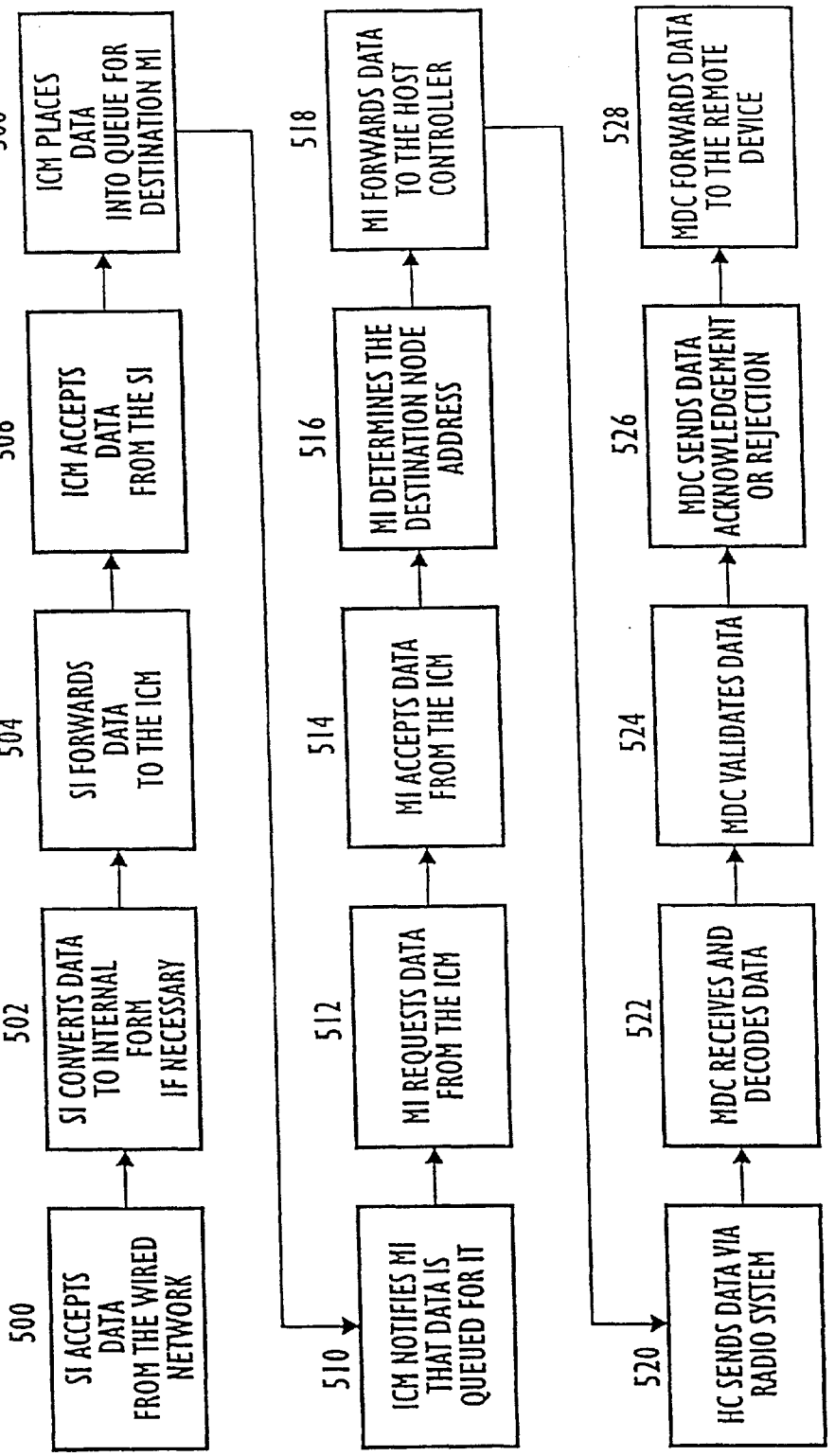

500
SI ACCEPTS DATA FROM THE WIRED NETWORK
502
SI CONVERTS DATA TO INTERNAL FORM IF NECESSARY
504
SI FORWARDS DATA TO THE ICM
506
ICM ACCEPTS DATA FROM THE SI
508
ICM PLACES DATA INTO QUEUE FOR DESTINATION MI
510
ICM NOTIFIES MI THAT DATA IS QUEUED FOR IT
512
MI REQUESTS DATA FROM THE ICM
514
MI ACCEPTS DATA FROM THE ICM
516
MI DETERMINES THE DESTINATION NODE ADDRESS
518
MI FORWARDS DATA TO THE HOST CONTROLLER
520
HC SENDS DATA VIA RADIO SYSTEM
522
MDC RECEIVES AND DECODES DATA
524
MDC VALIDATES DATA
526
MDC SENDS DATA ACKNOWLEDGEMENT OR REJECTION
528
MDC FORWARDS DATA TO THE REMOTE DEVICE

FIG. 4

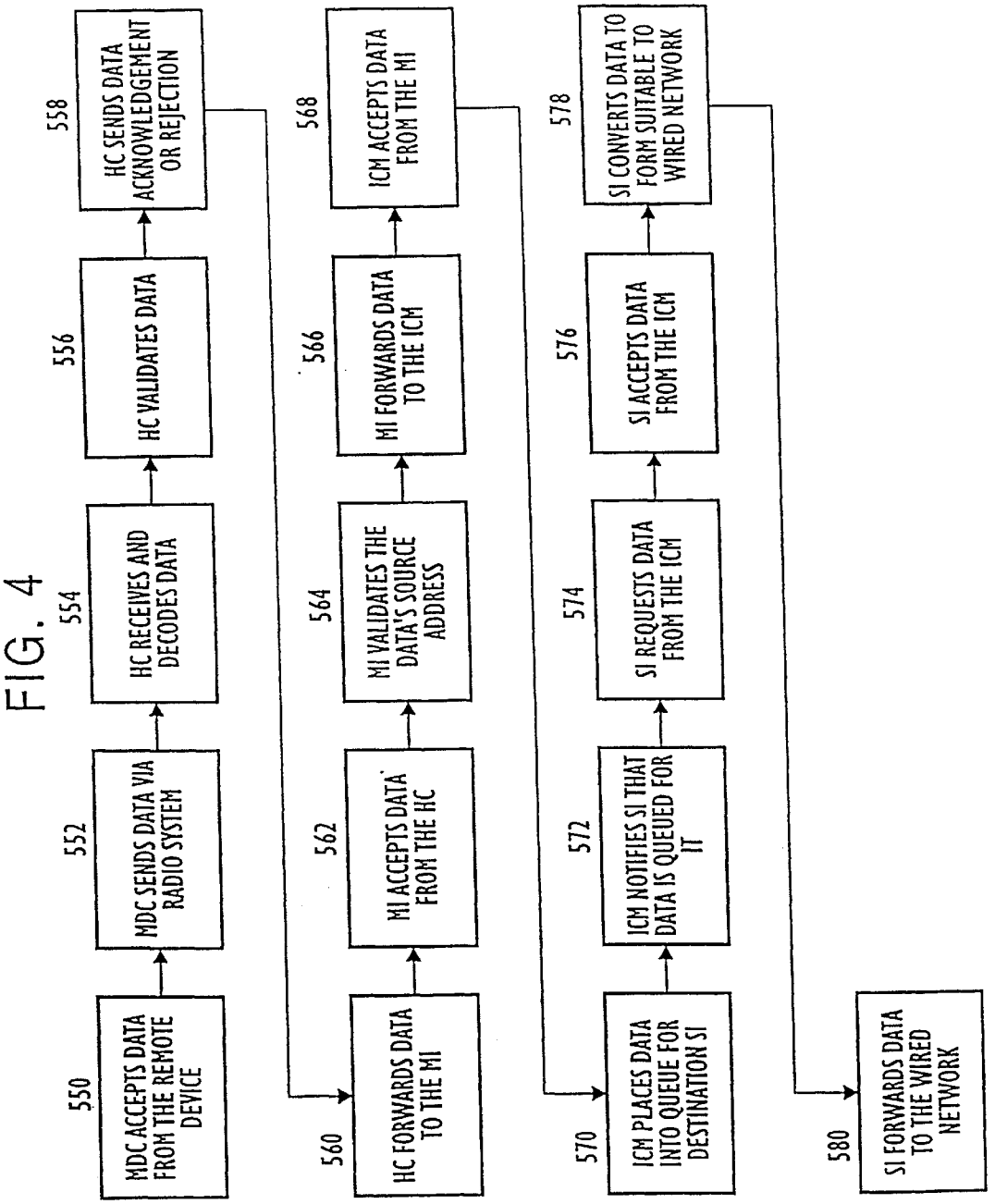

550
MDC ACCEPTS DATA FROM THE REMOTE DEVICE
552
MDC SENDS DATA VIA RADIO SYSTEM
554
HC RECEIVES AND DECODES DATA
556
HC VALIDATES DATA
558
HC SENDS DATA ACKNOWLEDGEMENT OR REJECTION
560
HC FORWARDS DATA TO THE MI
562
MI ACCEPTS DATA FROM THE HC
564
MI VALIDATES THE DATA'S SOURCE ADDRESS
566
MI FORWARDS DATA TO THE ICM
568
ICM ACCEPTS DATA FROM THE MI
570
ICM PLACES DATA INTO QUEUE FOR DESTINATION SI
572
ICM NOTIFIES SI THAT DATA IS QUEUED FOR IT
574
SI REQUESTS DATA FROM THE ICM
576
SI ACCEPTS DATA FROM THE ICM
578
SI CONVERTS DATA TO FORM SUITABLE TO WIRED NETWORK
580
SI FORWARDS DATA TO THE WIRED NETWORK

FIG. 5

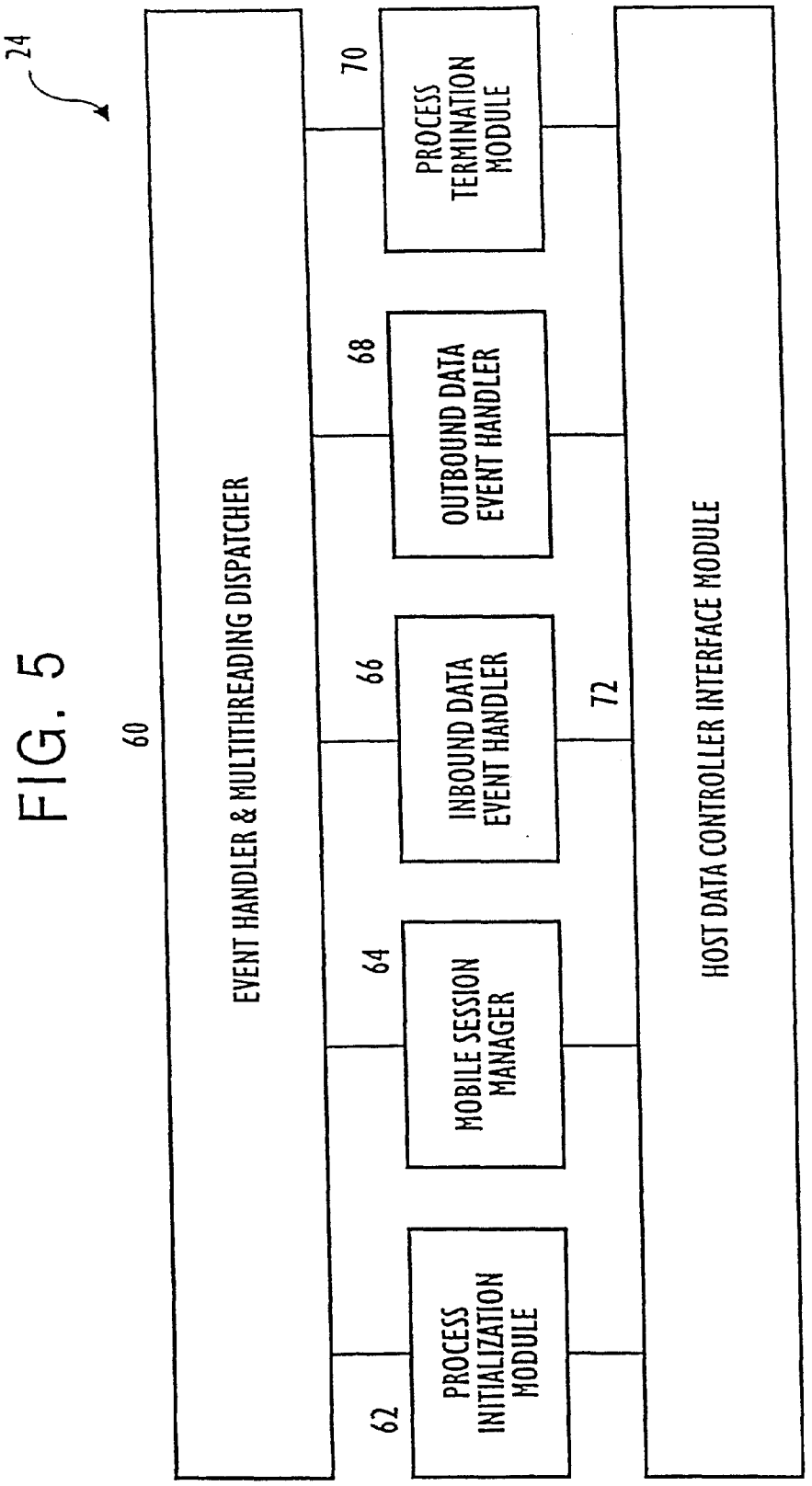

24
60
EVENT HANDLER & MULTITHREADING DISPATCHER
62
PROCESS INITIALIZATION MODULE
64
MOBILE SESSION MANAGER
66
INBOUND DATA EVENT HANDLER
68
OUTBOUND DATA EVENT HANDLER
70
PROCESS TERMINATION MODULE
72
HOST DATA CONTROLLER INTERFACE MODULE

FIG. 6

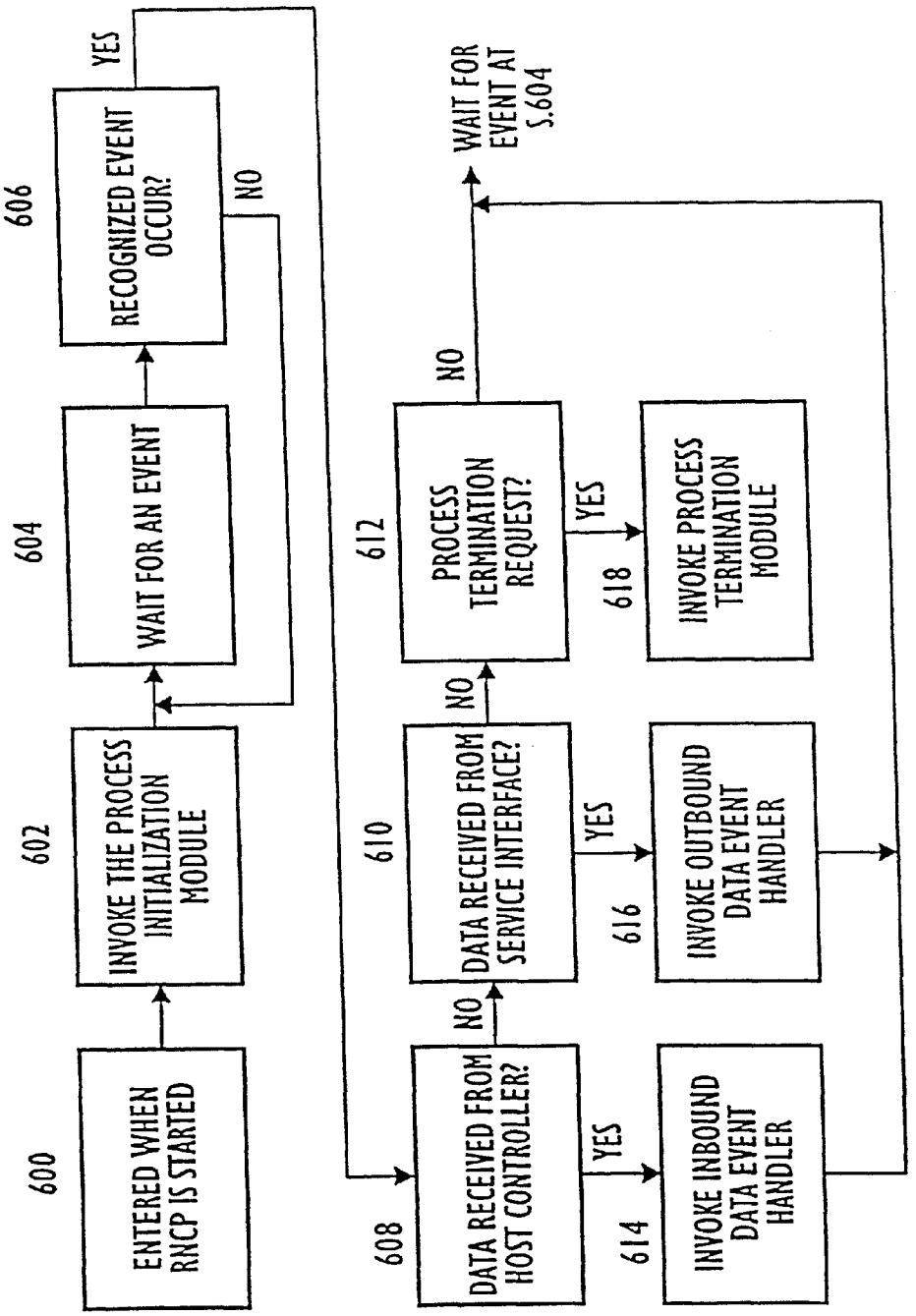

600
ENTERED WHEN RNCP IS STARTED
602
INVOKE THE PROCESS INITIALIZATION MODULE
604
WAIT FOR AN EVENT
606
RECOGNIZED EVENT OCCUR?
YES
NO
608
DATA RECEIVED FROM HOST CONTROLLER?
NO
YES
610
DATA RECEIVED FROM SERVICE INTERFACE?
NO
YES
612
PROCESS TERMINATION REQUEST?
NO
YES
614
INVOKE INBOUND DATA EVENT HANDLER
616
INVOKE OUTBOUND DATA EVENT HANDLER
618
INVOKE PROCESS TERMINATION MODULE
WAIT FOR EVENT AT S.604

FIG. 7

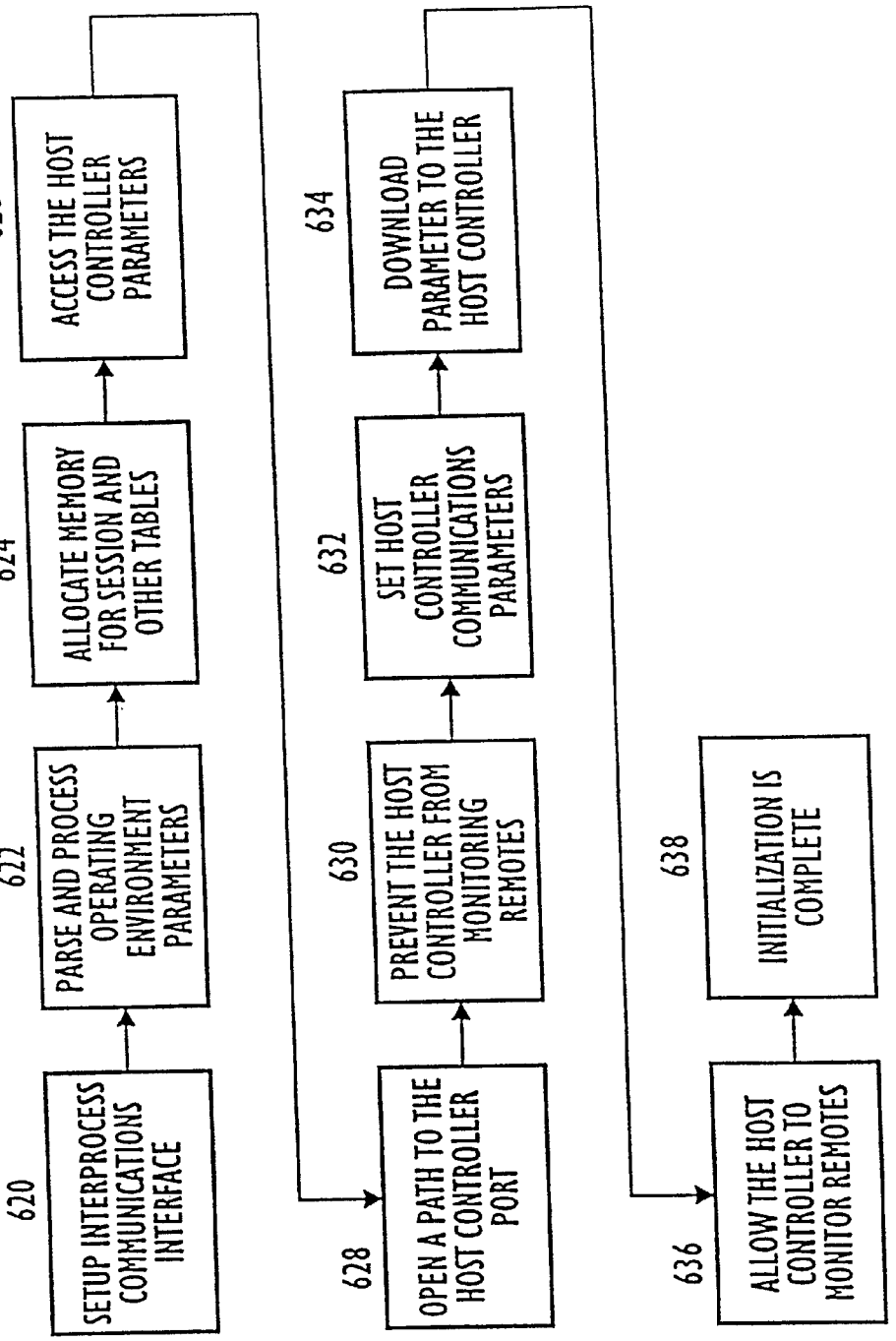
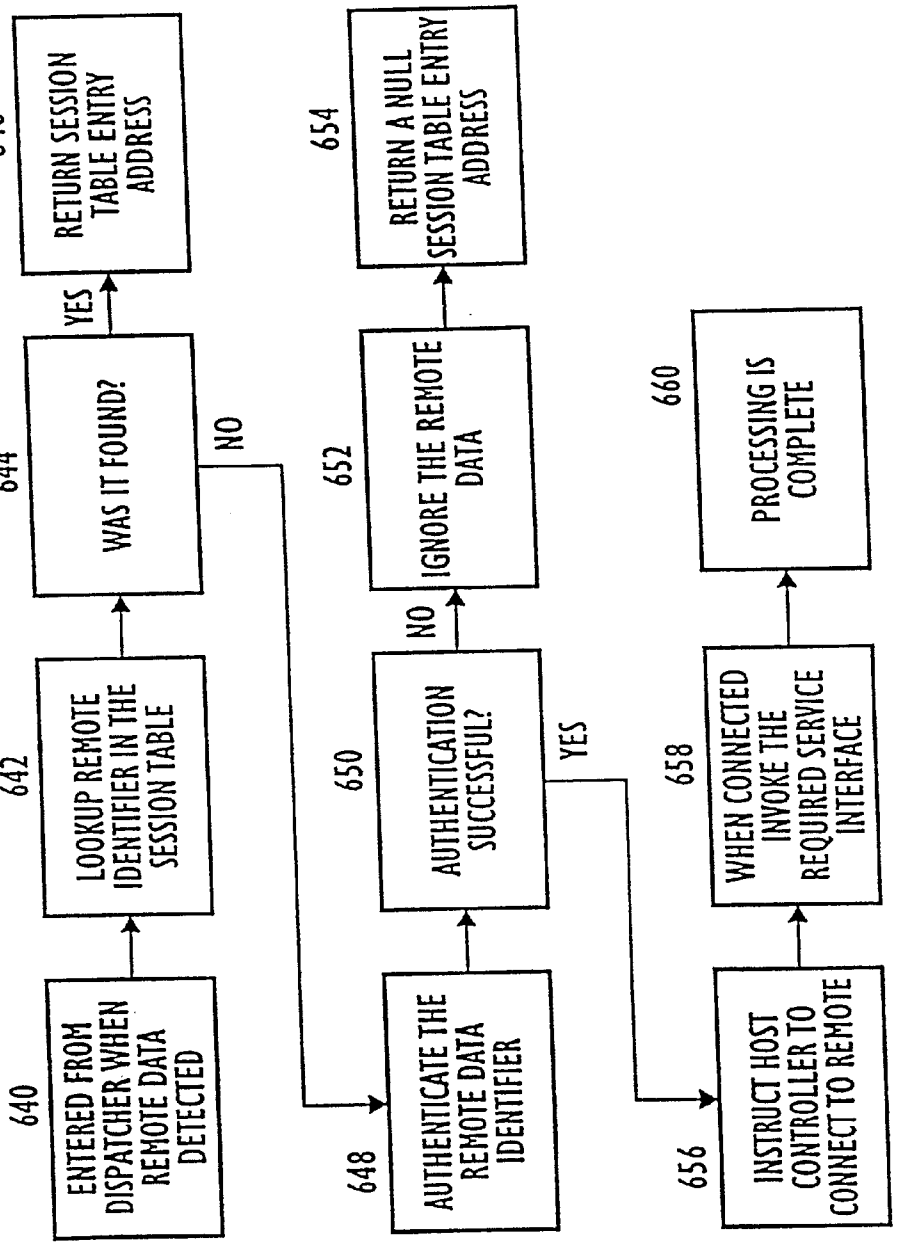

620
SETUP INTERPROCESS COMMUNICATIONS INTERFACE
622
PARSE AND PROCESS OPERATING ENVIRONMENT PARAMETERS
624
ALLOCATE MEMORY FOR SESSION AND OTHER TABLES
626
ACCESS THE HOST CONTROLLER PARAMETERS
628
OPEN A PATH TO THE HOST CONTROLLER PORT
630
PREVENT THE HOST CONTROLLER FROM MONITORING REMOTES
632
SET HOST CONTROLLER COMMUNICATIONS PARAMETERS
634
DOWNLOAD PARAMETER TO THE HOST CONTROLLER
636
ALLOW THE HOST CONTROLLER TO MONITOR REMOTES
638
INITIALIZATION IS COMPLETE

FIG. 8


640
ENTERED FROM DISPATCHER WHEN REMOTE DATA DETECTED
642
LOOKUP REMOTE IDENTIFIER IN THE SESSION TABLE
644
WAS IT FOUND?
YES
646
RETURN SESSION TABLE ENTRY ADDRESS
NO
648
AUTHENTICATE THE REMOTE DATA IDENTIFIER
650
AUTHENTICATION SUCCESSFUL?
NO
652
IGNORE THE REMOTE DATA
654
RETURN A NULL SESSION TABLE ENTRY ADDRESS
YES
656
INSTRUCT HOST CONTROLLER TO CONNECT TO REMOTE
658
WHEN CONNECTED INVOKE THE REQUIRED SERVICE INTERFACE
660
PROCESSING IS COMPLETE

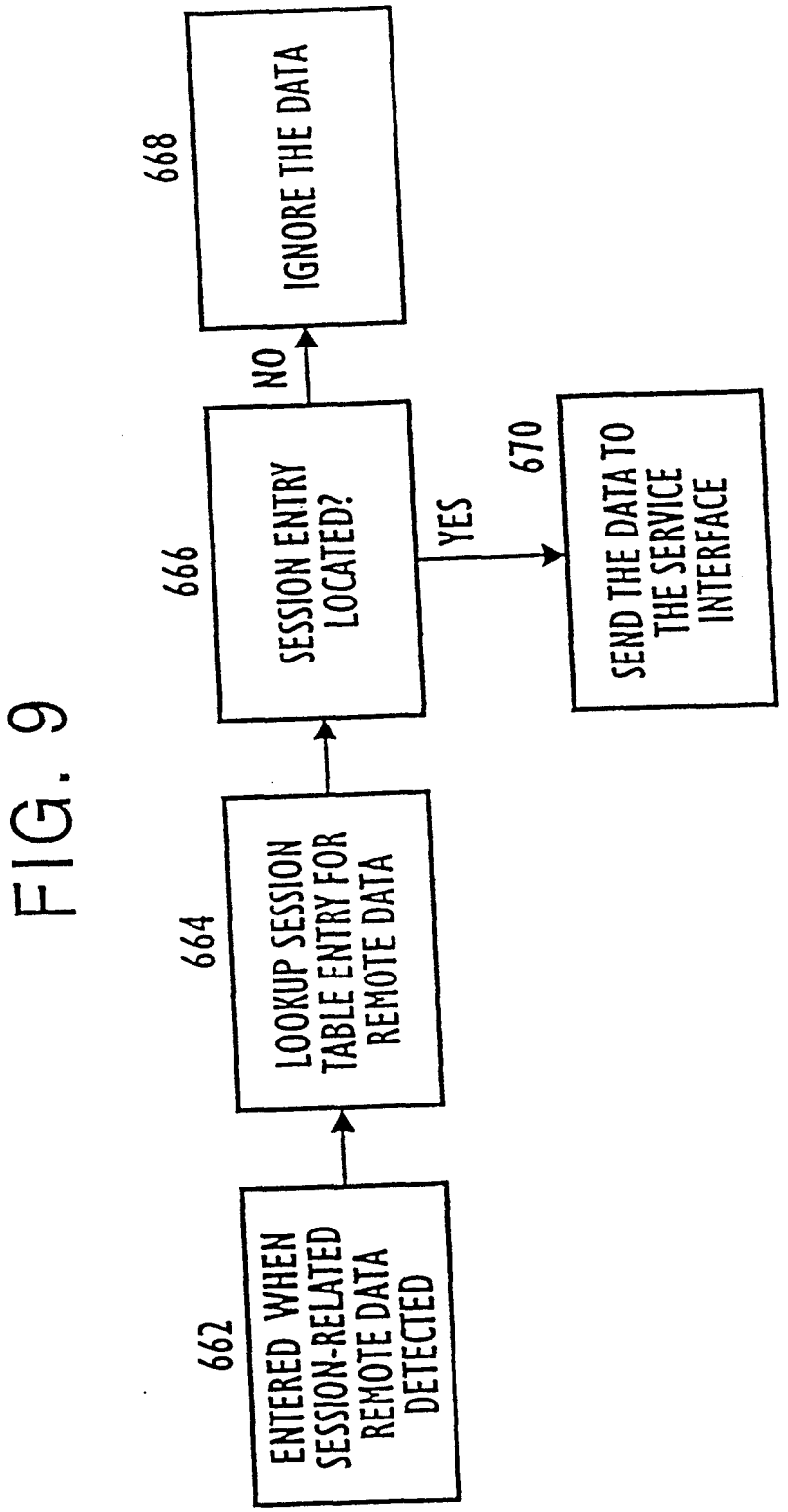

662
ENTERED WHEN SESSION-RELATED REMOTE DATA DETECTED
664
LOOKUP SESSION TABLE ENTRY FOR REMOTE DATA
666
SESSION ENTRY LOCATED?
YES
670
SEND THE DATA TO THE SERVICE INTERFACE
NO
668
IGNORE THE DATA

FIG. 9

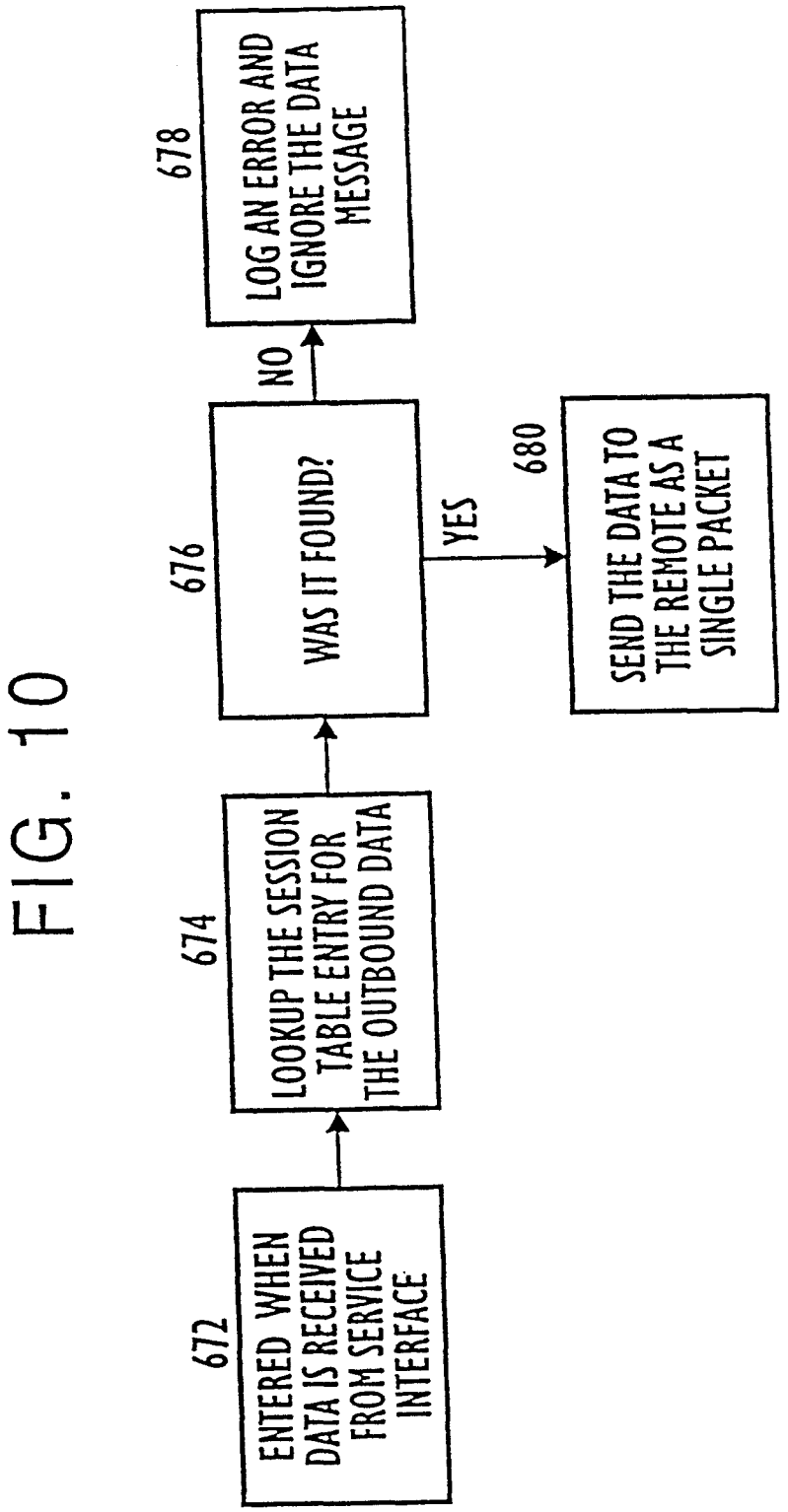

672
ENTERED WHEN DATA IS RECEIVED FROM SERVICE INTERFACE
674
LOOKUP THE SESSION TABLE ENTRY FOR THE OUTBOUND DATA
676
WAS IT FOUND?
NO
678
LOG AN ERROR AND IGNORE THE DATA MESSAGE
YES
680
SEND THE DATA TO THE REMOTE AS A SINGLE PACKET

FIG. 10

FIG. 11

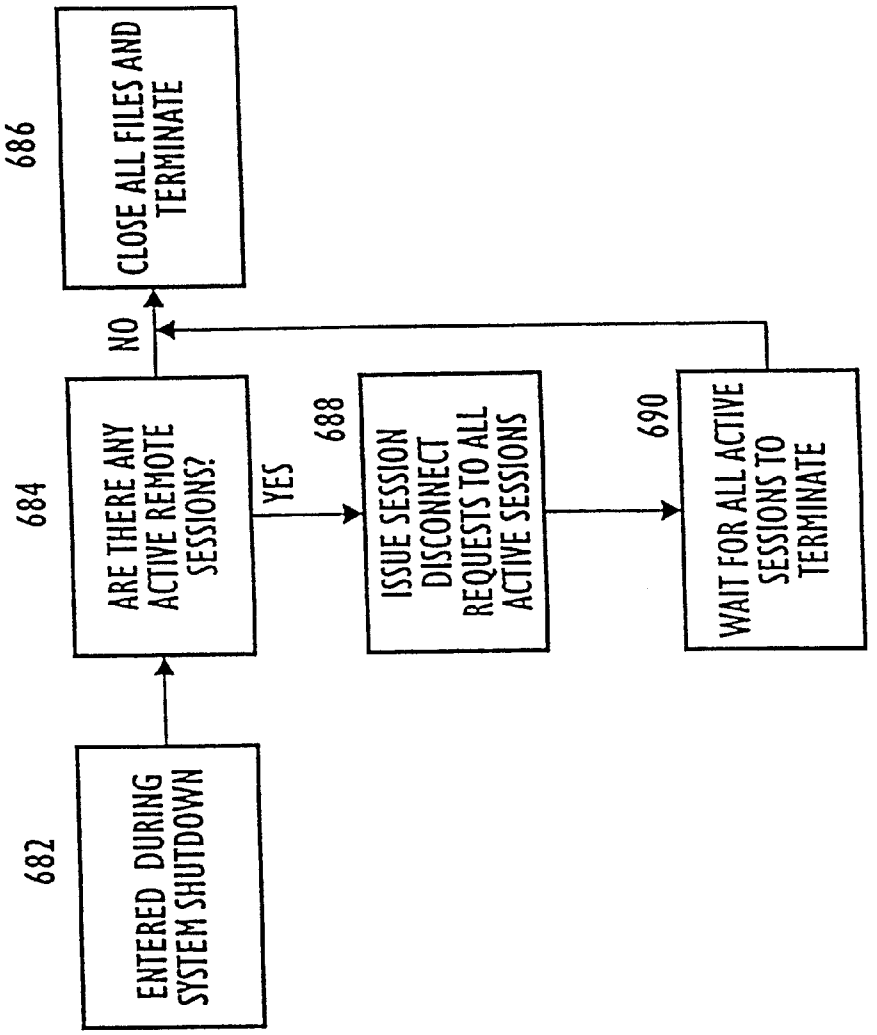

682
ENTERED DURING SYSTEM SHUTDOWN
684
ARE THERE ANY ACTIVE REMOTE SESSIONS?
YES
688
ISSUE SESSION DISCONNECT REQUESTS TO ALL ACTIVE SESSIONS
690
WAIT FOR ALL ACTIVE SESSIONS TO TERMINATE
NO
686
CLOSE ALL FILES AND TERMINATE

FIG. 12

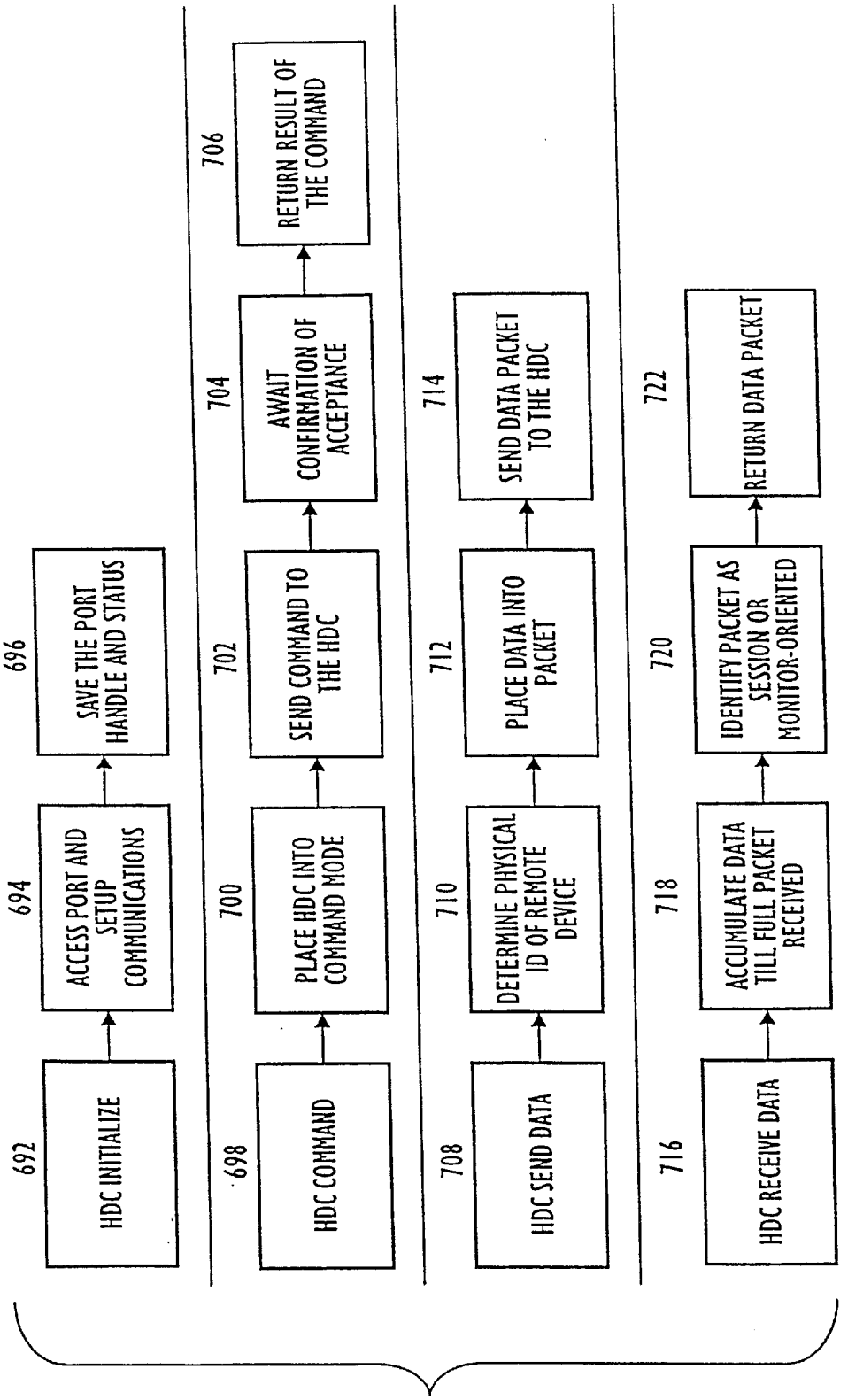
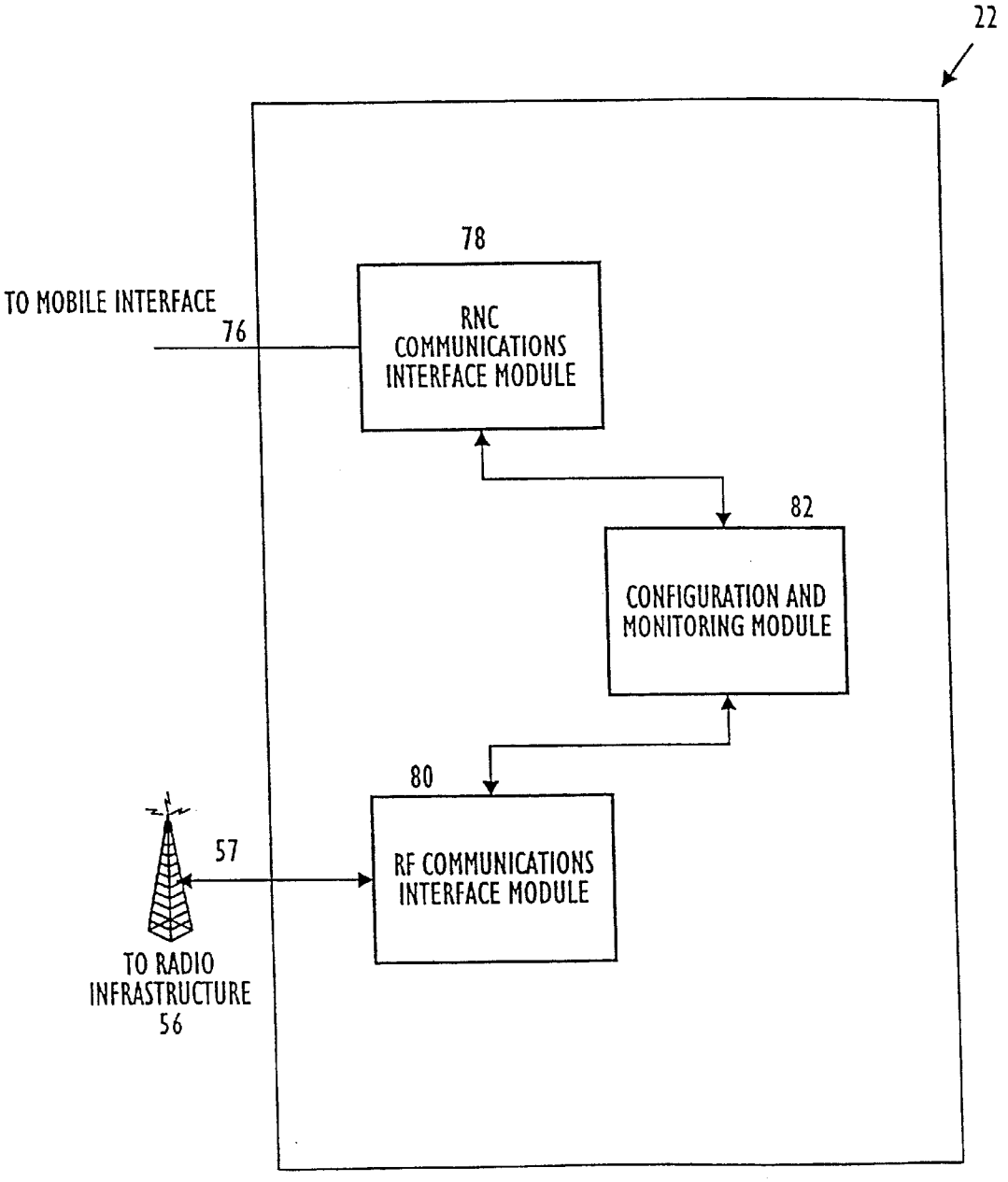

692
HDC INITIALIZE
694
ACCESS PORT AND SETUP COMMUNICATIONS
696
SAVE THE PORT HANDLE AND STATUS
698
HDC COMMAND
700
PLACE HDC INTO COMMAND MODE
702
SEND COMMAND TO THE HDC
704
AWAIT CONFIRMATION OF ACCEPTANCE
706
RETURN RESULT OF THE COMMAND
708
HDC SEND DATA
710
DETERMINE PHYSICAL ID OF REMOTE DEVICE
712
PLACE DATA INTO PACKET
714
SEND DATA PACKET TO THE HDC
716
HDC RECEIVE DATA
718
ACCUMULATE DATA TILL FULL PACKET RECEIVED
720
IDENTIFY PACKET AS SESSION OR MONITOR-ORIENTED
722
RETURN DATA PACKET

FIG 13


22
78
TO MOBILE INTERFACE
76
RNC COMMUNICATIONS INTERFACE MODULE
82
CONFIGURATION AND MONITORING MODULE
80
57
RF COMMUNICATIONS INTERFACE MODULE
TO RADIO INFRASTRUCTURE
56

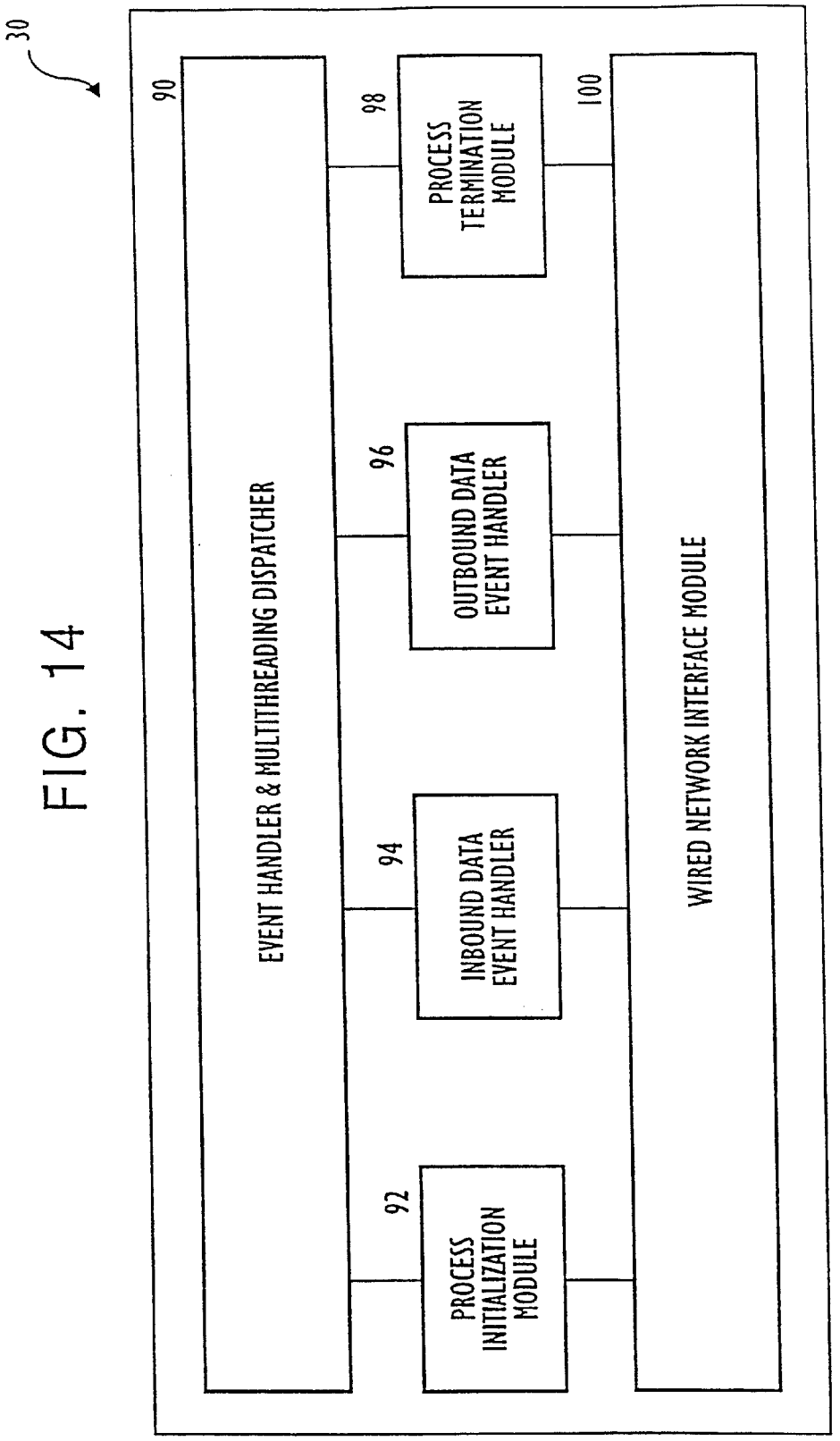

30
90
EVENT HANDLER & MULITITHREADING DISPATCHER
92
PROCESS INITIALIZATION MODULE
94
INBOUND DATA EVENT HANDLER
96
OUTBOUND DATA EVENT HANDLER
98
PROCESS TERMINATION MODULE
100
WIRED NETWORK INTERFACE MODULE

FIG. 14

FIG. 15

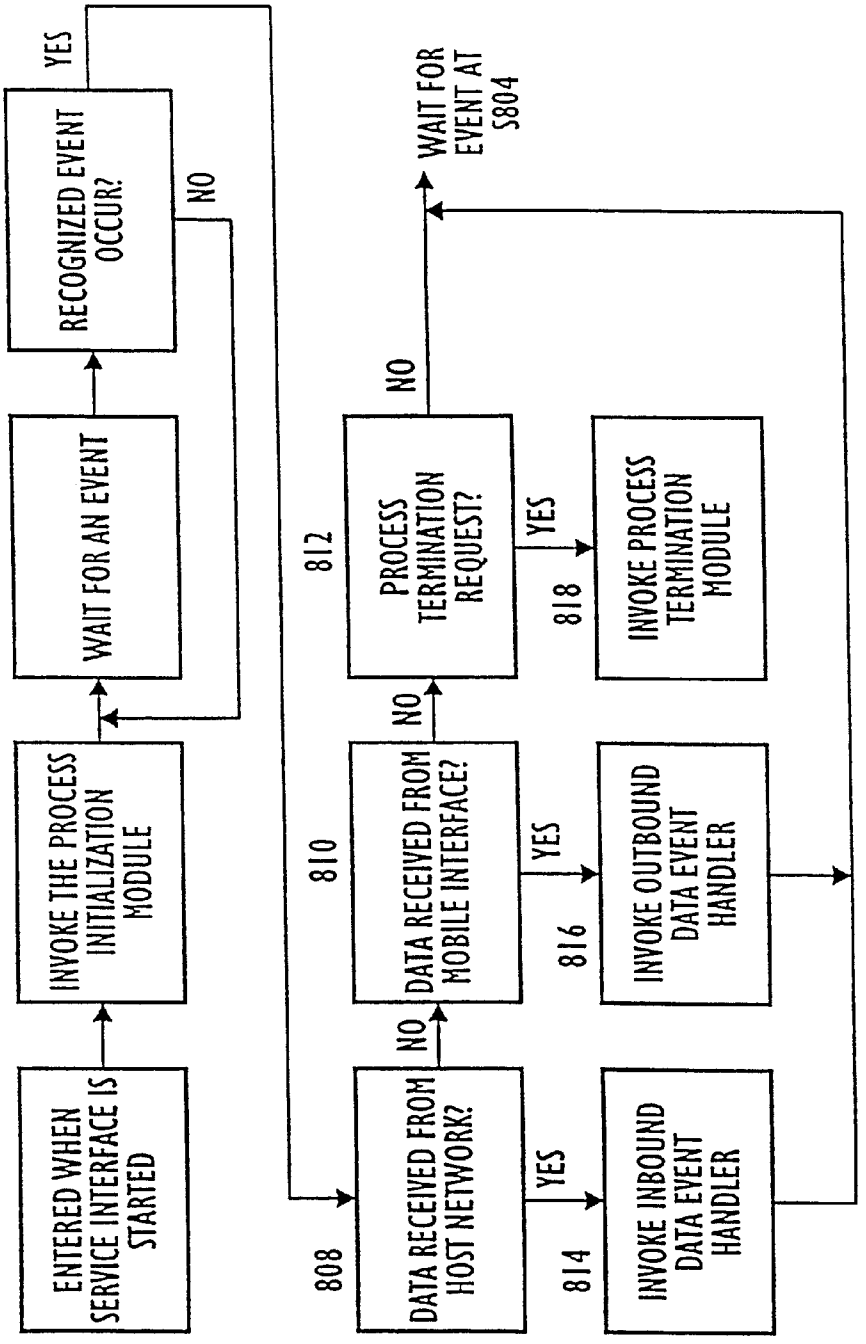

800
ENTERED WHEN SERVICE INTERFACE IS STARTED
802
INVOKE THE PROCESS INITIALIZATION MODULE
804
WAIT FOR AN EVENT
806
RECOGNIZED EVENT OCCUR?
YES
NO
808
DATA RECEIVED FROM HOST NETWORK?
NO
YES
810
DATA RECEIVED FROM MOBILE INTERFACE?
NO
YES
812
PROCESS TERMINATION REQUEST?
NO
YES
814
INVOKE INBOUND DATA EVENT HANDLER
816
INVOKE OUTBOUND DATA EVENT HANDLER
818
INVOKE PROCESS TERMINATION MODULE
WAIT FOR EVENT AT S804

FIG. 16

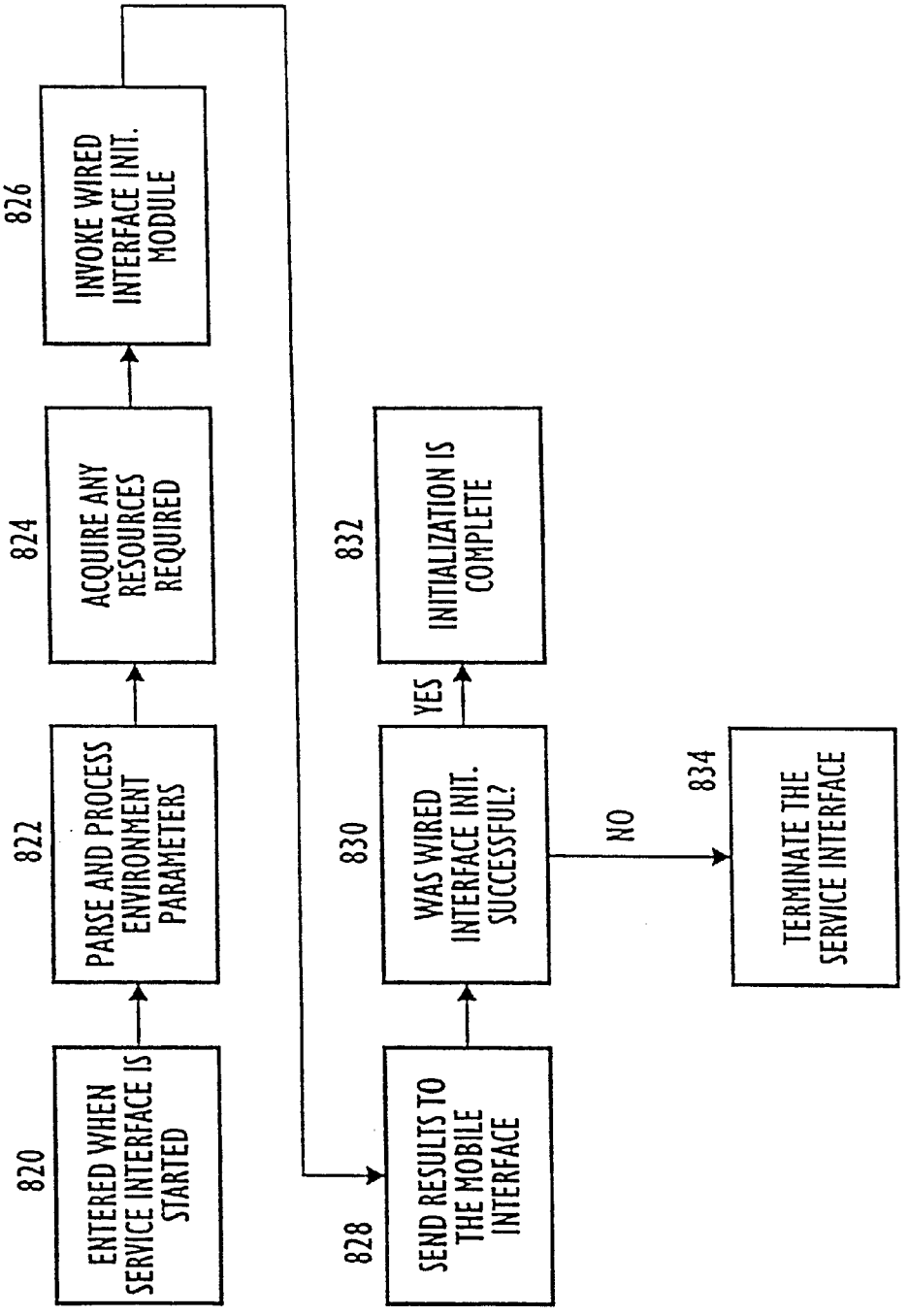

820
ENTERED WHEN SERVICE INTERFACE IS STARTED
822
PARSE AND PROCESS ENVIRONMENT PARAMETERS
824
ACQUIRE ANY RESOURCES REQUIRED
826
INVOKE WIRED INTERFACE INIT. MODULE
828
SEND RESULTS TO THE MOBILE INTERFACE
830
WAS WIRED INTERFACE INIT. SUCCESSFUL?
YES
NO
832
INITIALIZATION IS COMPLETE
834
TERMINATE THE SERVICE INTERFACE

FIG. 17

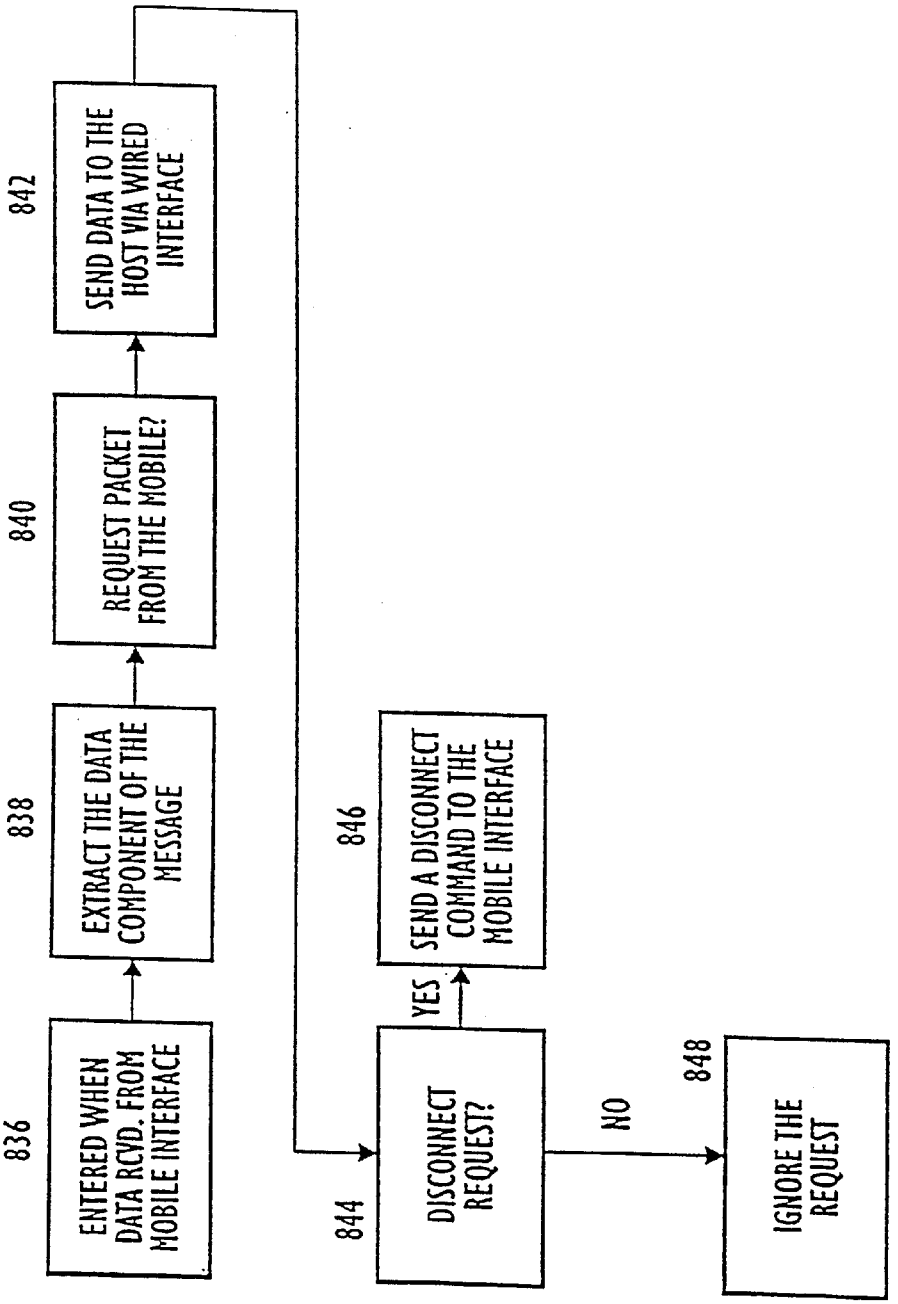

836
ENTERED WHEN DATA RCVD. FROM MOBILE INTERFACE
838
EXTRACT THE DATA COMPONENT OF THE MESSAGE
840
REQUEST PACKET FROM THE MOBILE?
842
SEND DATA TO THE HOST VIA WIRED INTERFACE
844
DISCONNECT REQUEST?
YES
846
SEND A DISCONNECT COMMAND TO THE MOBILE INTERFACE
NO
848
IGNORE THE REQUEST

FIG. 18

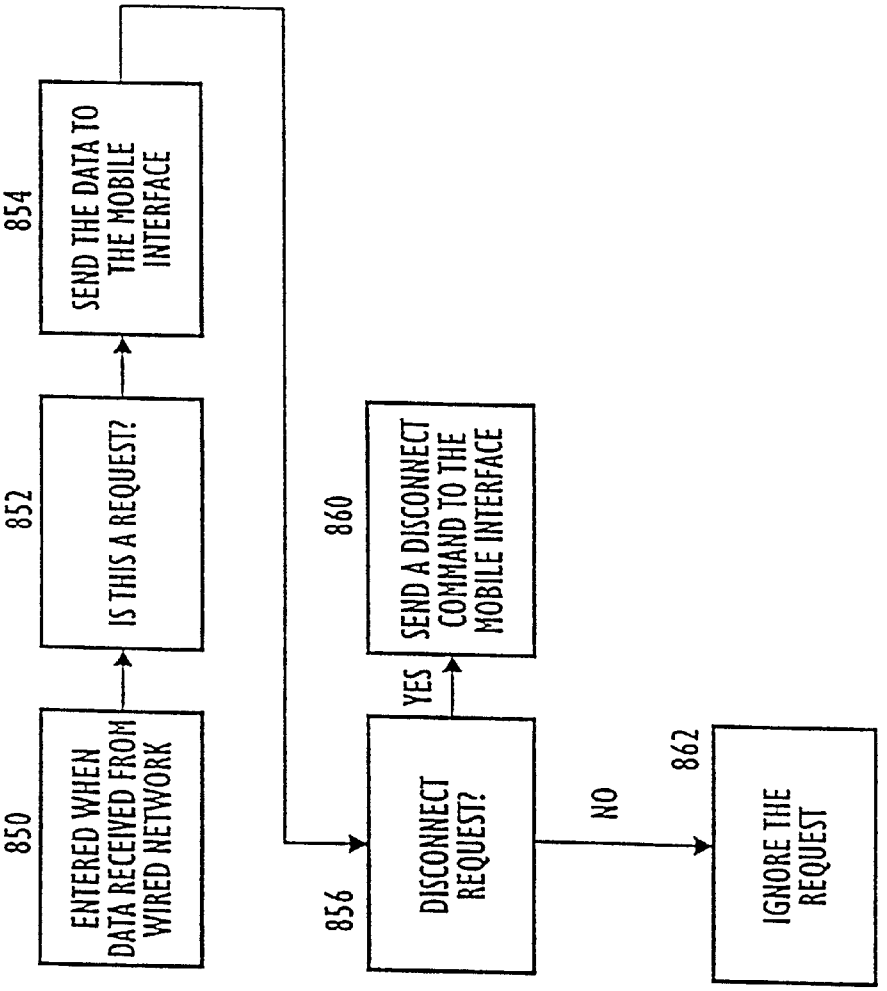

850
ENTERED WHEN DATA RECEIVED FROM WIRED NETWORK
852
IS THIS A REQUEST?
854
SEND THE DATA TO THE MOBILE INTERFACE
856
DISCONNECT REQUEST?
YES
860
SEND A DISCONNECT COMMAND TO THE MOBILE INTERFACE
NO
862
IGNORE THE REQUEST

FIG. 19

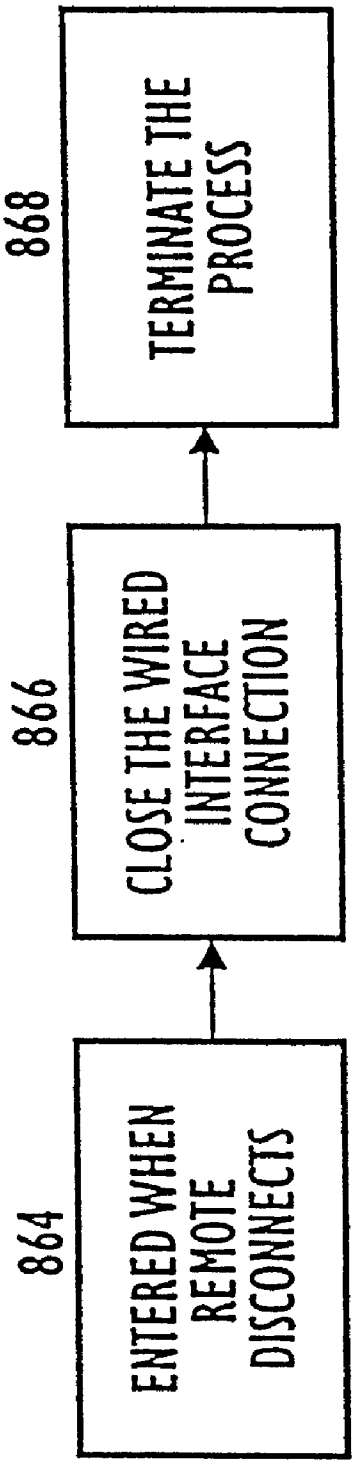

864
ENTERED WHEN REMOTE DISCONNECTS
866
CLOSE THE WIRED INTERFACE CONNECTION
868
TERMINATE THE PROCESS

FIG. 20

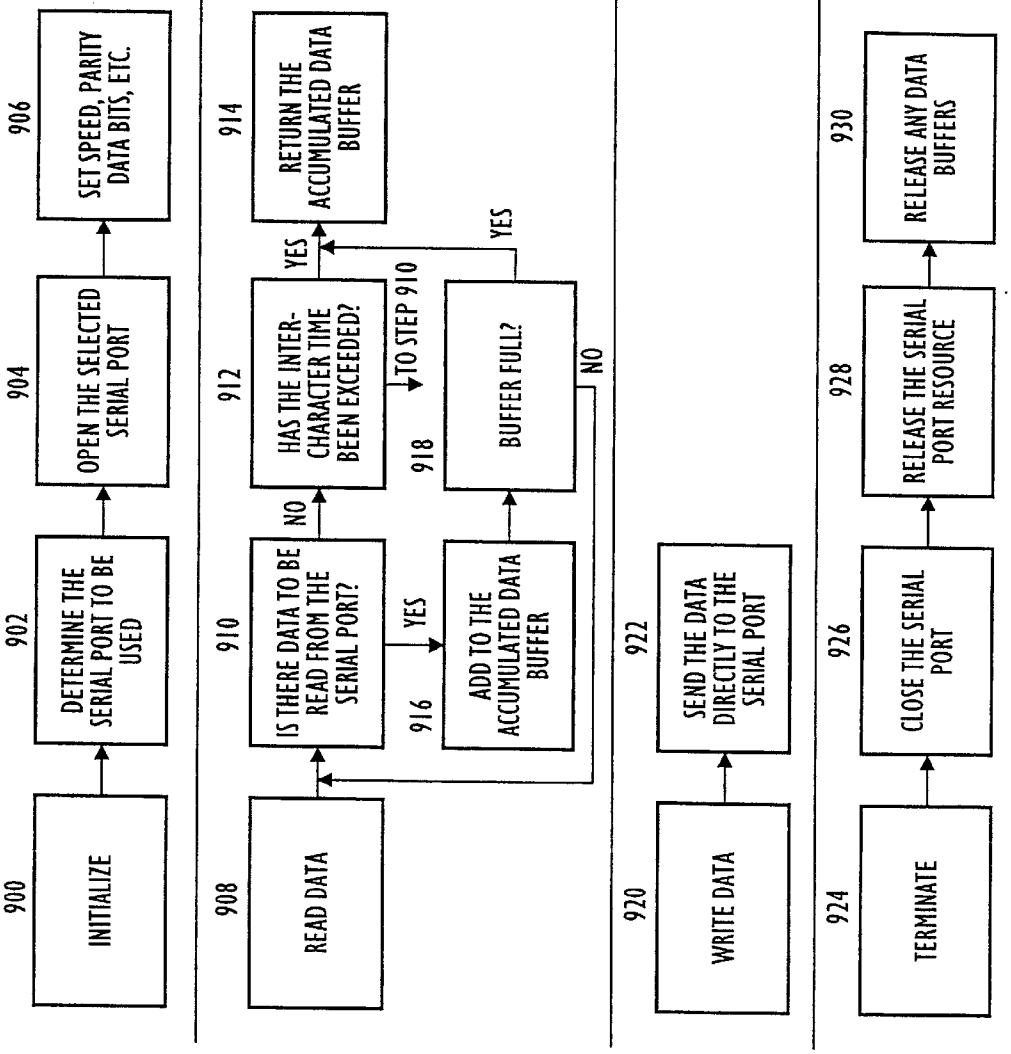

900
INITIALIZE
902
DETERMINE THE SERIAL PORT TO BE USED
904
OPEN THE SELECTED SERIAL PORT
906
SET SPEED, PARITY DATA BITS, ETC.
908
READ DATA
910
IS THERE DATA TO BE READ FROM THE SERIAL PORT?
NO
YES
912
HAS THE INTER-CHARACTER TIME BEEN EXCEEDED?
TO STEP 910
YES
914
RETURN THE ACCUMULATED DATA BUFFER
916
ADD TO THE ACCUMULATED DATA BUFFER
918
BUFFER FULL?
YES
NO
920
WRITE DATA
922
SEND THE DATA DIRECTLY TO THE SERIAL PORT
924
TERMINATE
926
CLOSE THE SERIAL PORT
928
RELEASE THE SERIAL PORT RESOURCE
930
RELEASE ANY DATA BUFFERS

FIG. 21

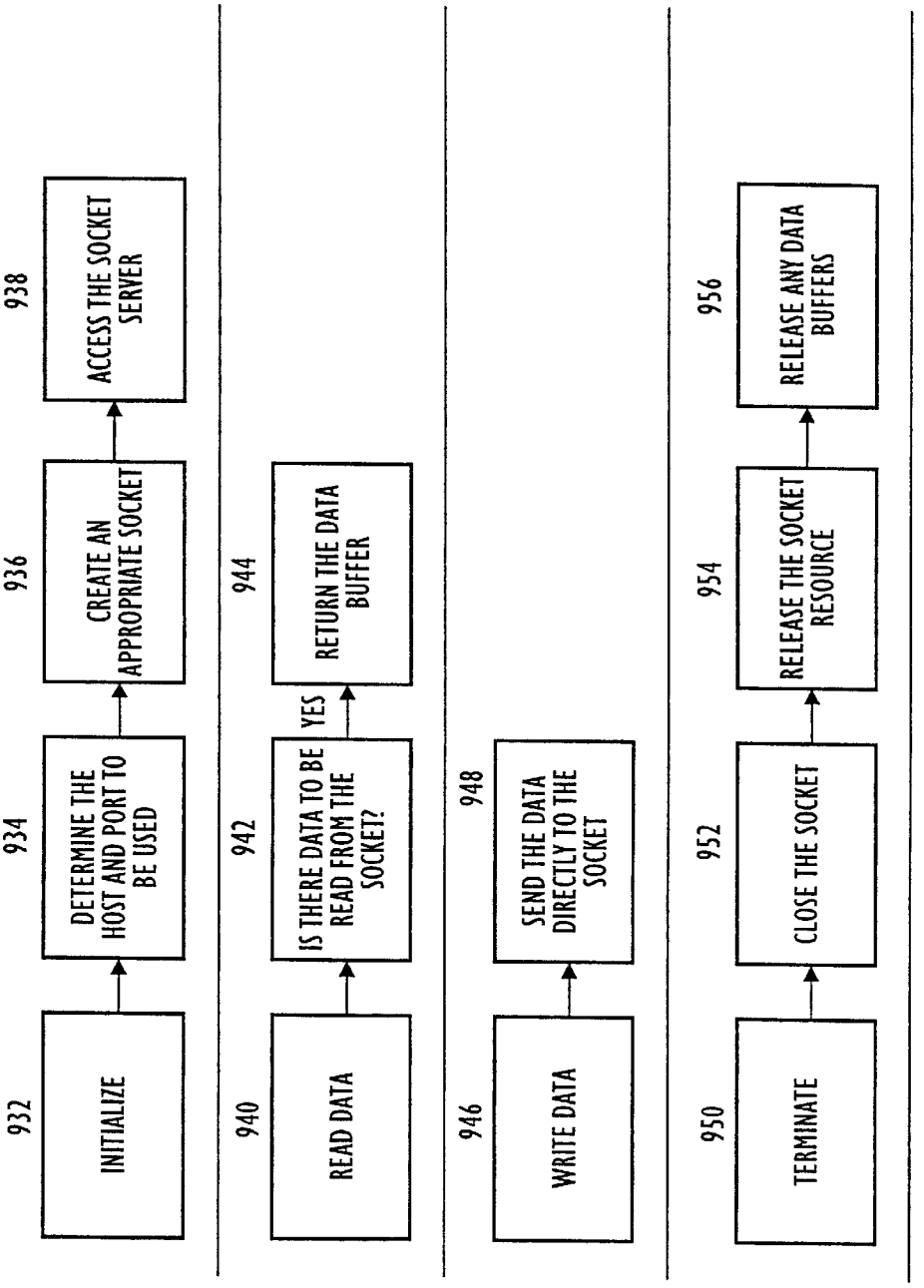

932
INITIALIZE
934
DETERMINE THE HOST AND PORT TO BE USED
936
CREATE AN APPROPRIATE SOCKET
938
ACCESS THE SOCKET SERVER
940
READ DATA
942
IS THERE DATA TO BE READ FROM THE SOCKET?
YES
944
RETURN THE DATA BUFFER
946
WRITE DATA
948
SEND THE DATA DIRECTLY TO THE SOCKET
950
TERMINATE
952
CLOSE THE SOCKET
954
RELEASE THE SOCKET RESOURCE
956
RELEASE ANY DATA BUFFERS

FIG. 22

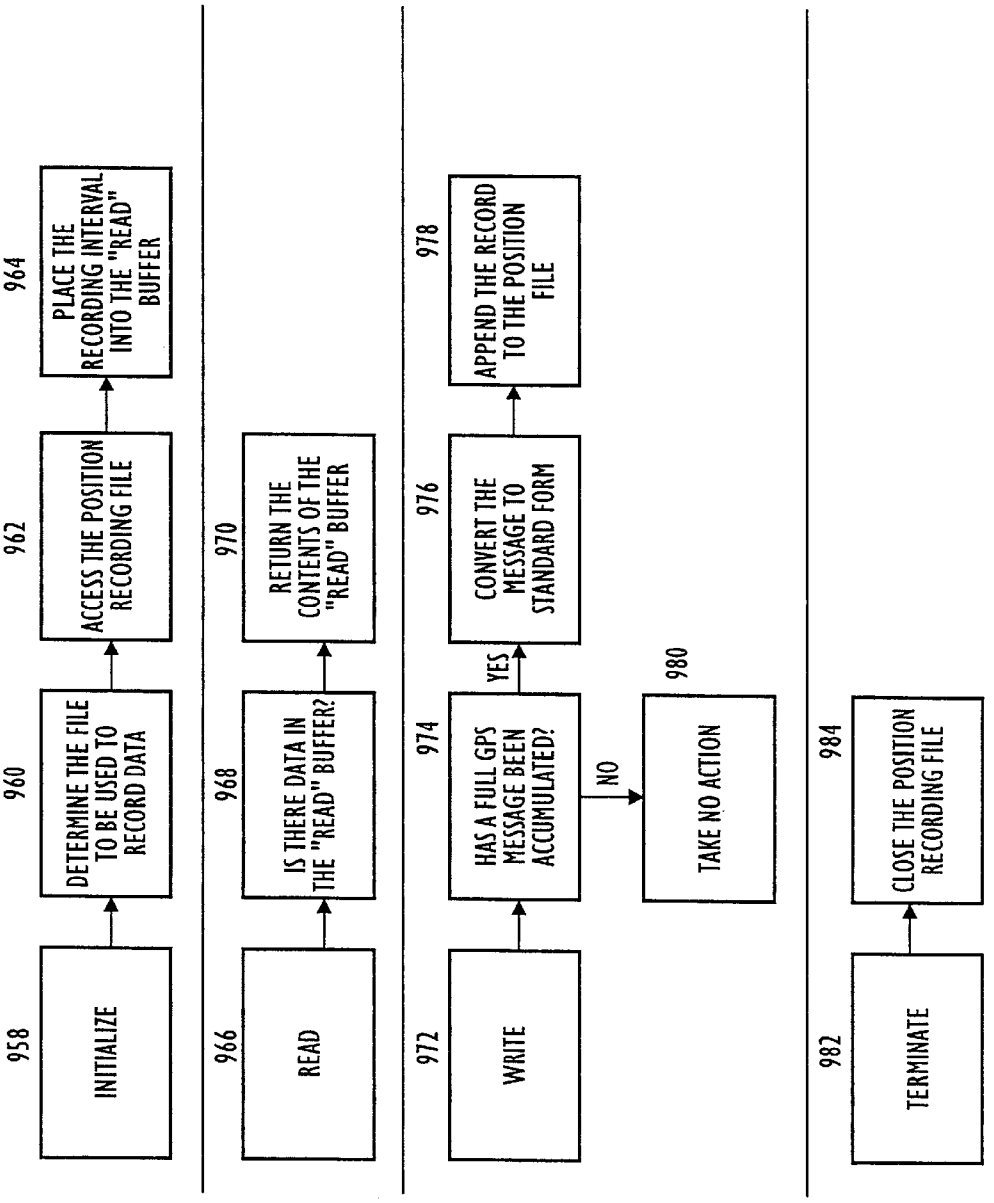

958
INITIALIZE
960
DETERMINE THE FILE TO BE USED TO RECORD DATA
962
ACCESS THE POSITION RECORDING FILE
964
PLACE THE RECORDING INTERVAL INTO THE "READ" BUFFER
966
READ
968
IS THERE DATA IN THE "READ" BUFFER?
970
RETURN THE CONTENTS OF THE "READ" BUFFER
972
WRITE
974
HAS A FULL GPS MESSAGE BEEN ACCUMULATED?
YES
NO
976
CONVERT THE MESSAGE TO STANDARD FORM
978
APPEND THE RECORD TO THE POSITION FILE
980
TAKE NO ACTION
982
TERMINATE
984
CLOSE THE POSITION RECORDING FILE

FIG. 23A

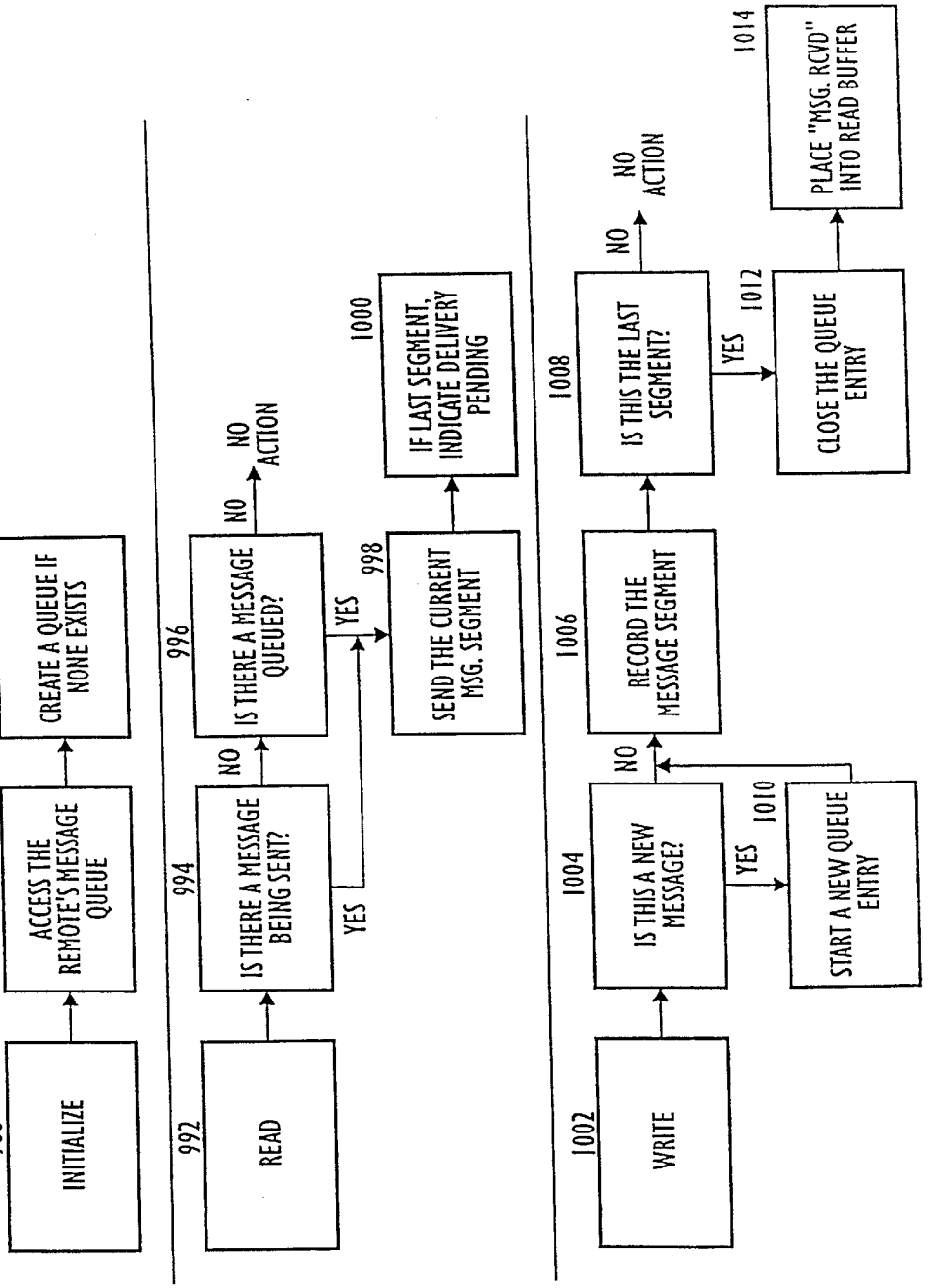

986
INITIALIZE
988
ACCESS THE REMOTE'S MESSAGE QUEUE
990
CREATE A QUEUE IF NONE EXISTS
992
READ
994
IS THERE A MESSAGE BEING SENT?
NO
YES
996
IS THERE A MESSAGE QUEUED?
NO
NO ACTION
YES
998
SEND THE CURRENT MSG. SEGMENT
1000
IF LAST SEGMENT, INDICATE DELIVERY PENDING
1002
WRITE
1004
IS THIS A NEW MESSAGE?
NO
YES
1006
RECORD THE MESSAGE SEGMENT
1008
IS THIS THE LAST SEGMENT?
NO
NO ACTION
YES
1010
START A NEW QUEUE ENTRY
1012
CLOSE THE QUEUE ENTRY
1014
PLACE "MSG. RCVD" INTO READ BUFFER

FIG. 23B

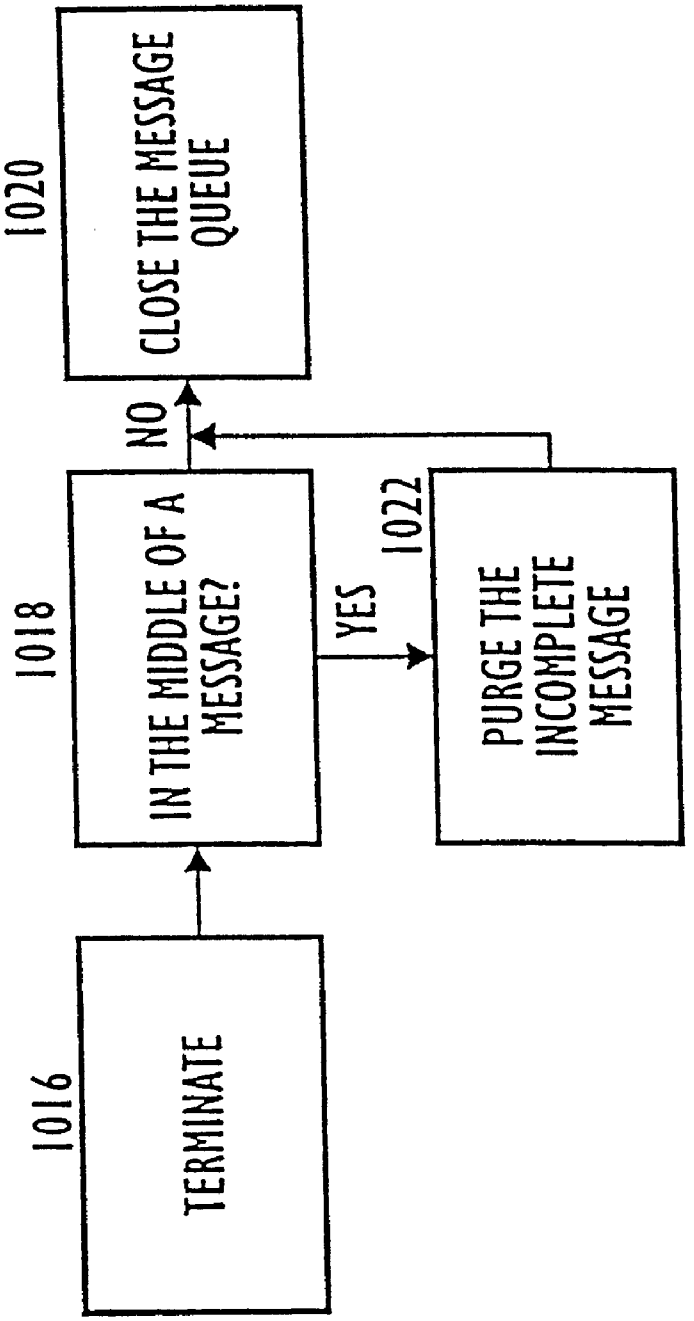

1016
TERMINATE
1018
IN THE MIDDLE OF A MESSAGE?
YES
1022
PURGE THE INCOMPLETE MESSAGE
NO
1020
CLOSE THE MESSAGE QUEUE

FIG. 24

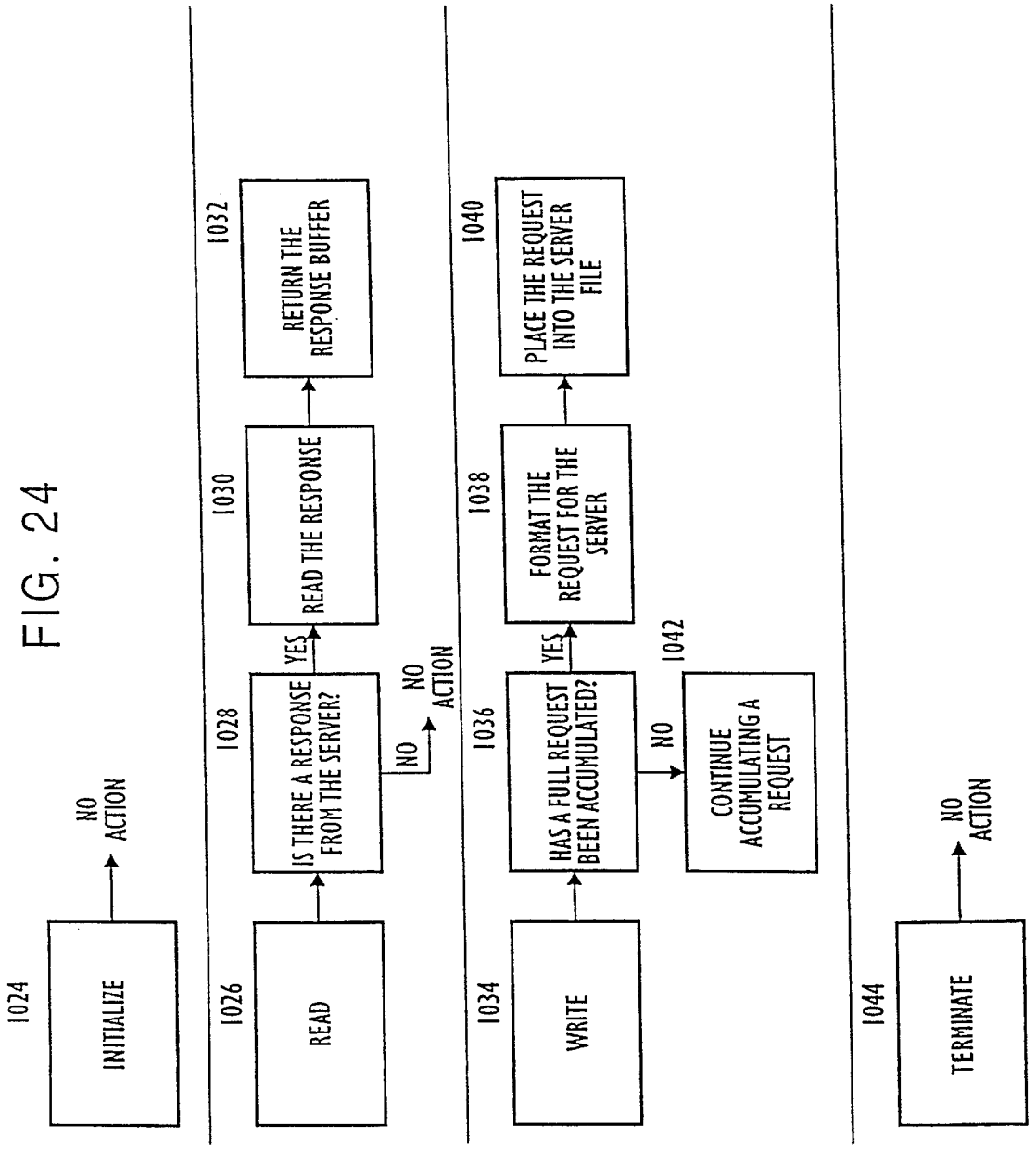

1024
INITIALIZE
NO ACTION
1026
READ
1028
IS THERE A RESPONSE FROM THE SERVER?
YES
NO
NO ACTION
1030
READ THE RESPONSE
1032
RETURN THE RESPONSE BUFFER
1034
WRITE
1036
HAS A FULL REQUEST BEEN ACCUMULATED?
YES
NO
1038
FORMAT THE REQUEST FOR THE SERVER
1040
PLACE THE REQUEST INTO THE SERVER FILE
1042
CONTINUE ACCUMULATING A REQUEST
1044
TERMINATE
NO ACTION

FIG 25

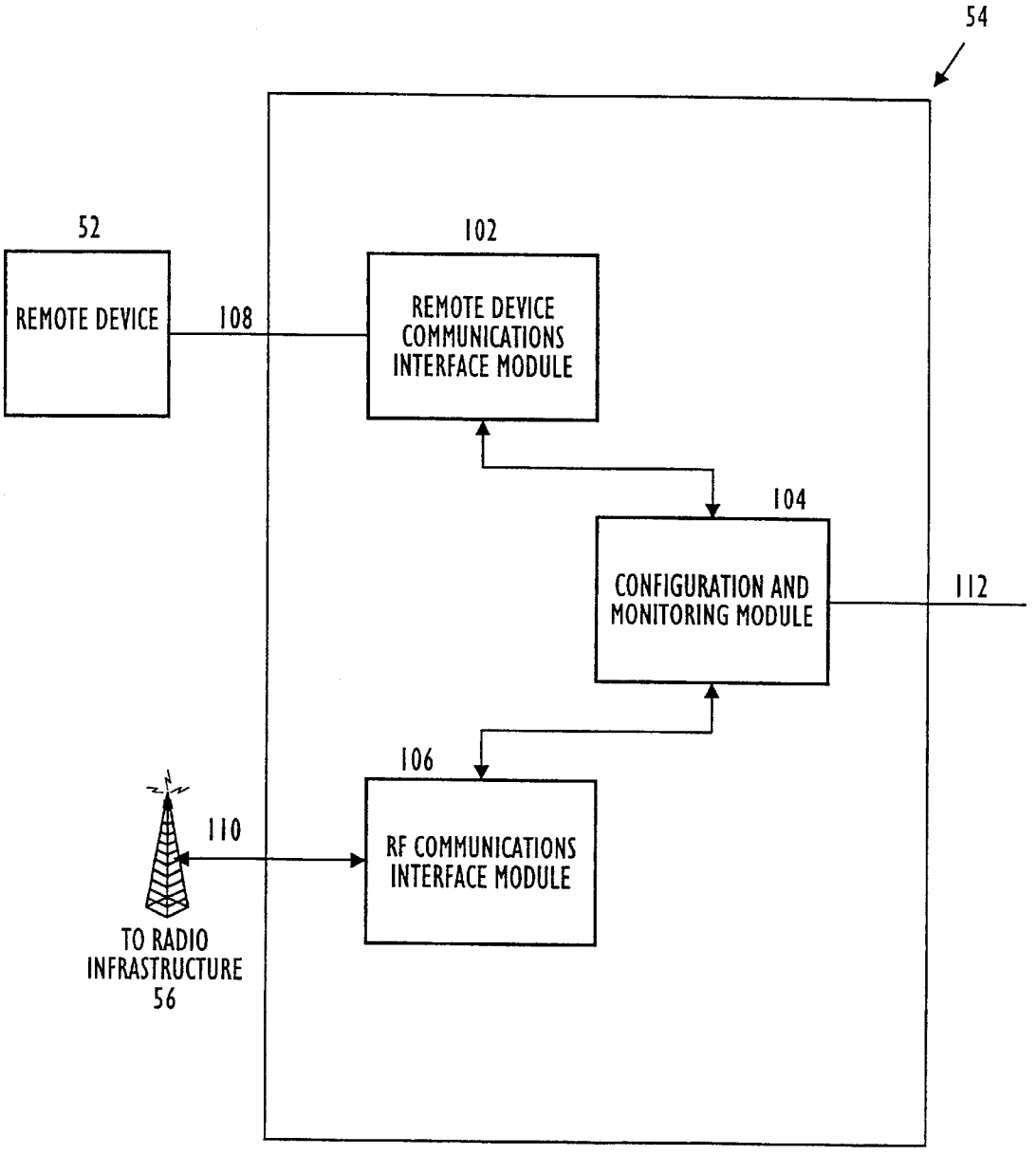

54
52
REMOTE DEVICE
108
102
REMOTE DEVICE COMMUNICATIONS INTERFACE MODULE
104
CONFIGURATION AND MONITORING MODULE
112
106
RF COMMUNICATIONS INTERFACE MODULE
110
TO RADIO INFRASTRUCTURE 56

FIG 26

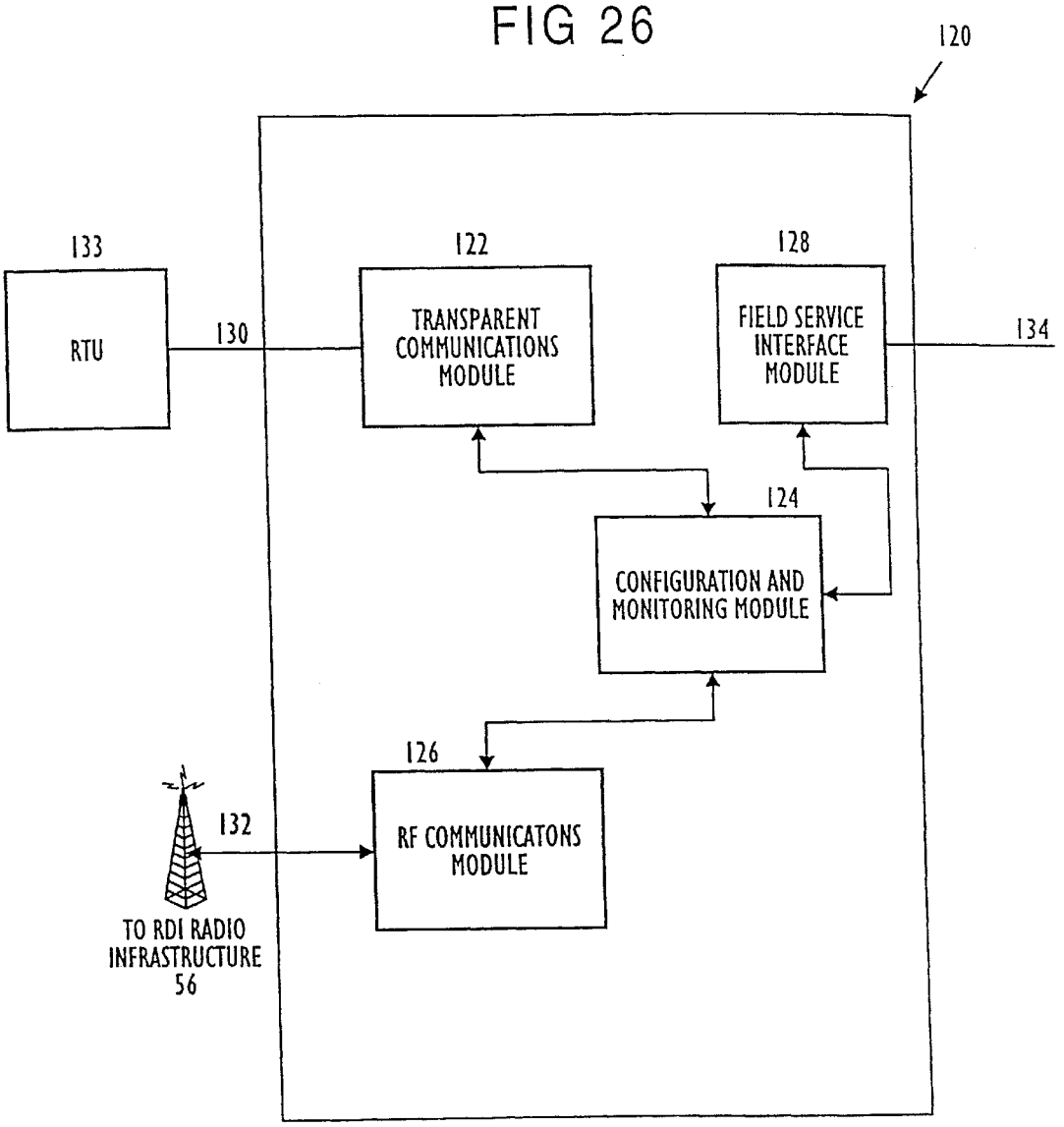

120
133
RTU
130
122
TRANSPARENT COMMUNICATIONS MODULE
128
FIELD SERVICE INTERFACE MODULE
134
124
CONFIGURATION AND MONITORING MODULE
126
RF COMMUNICATONS MODULE
132
TO RDI RADIO INFRASTRUCTURE 56

FIG 27

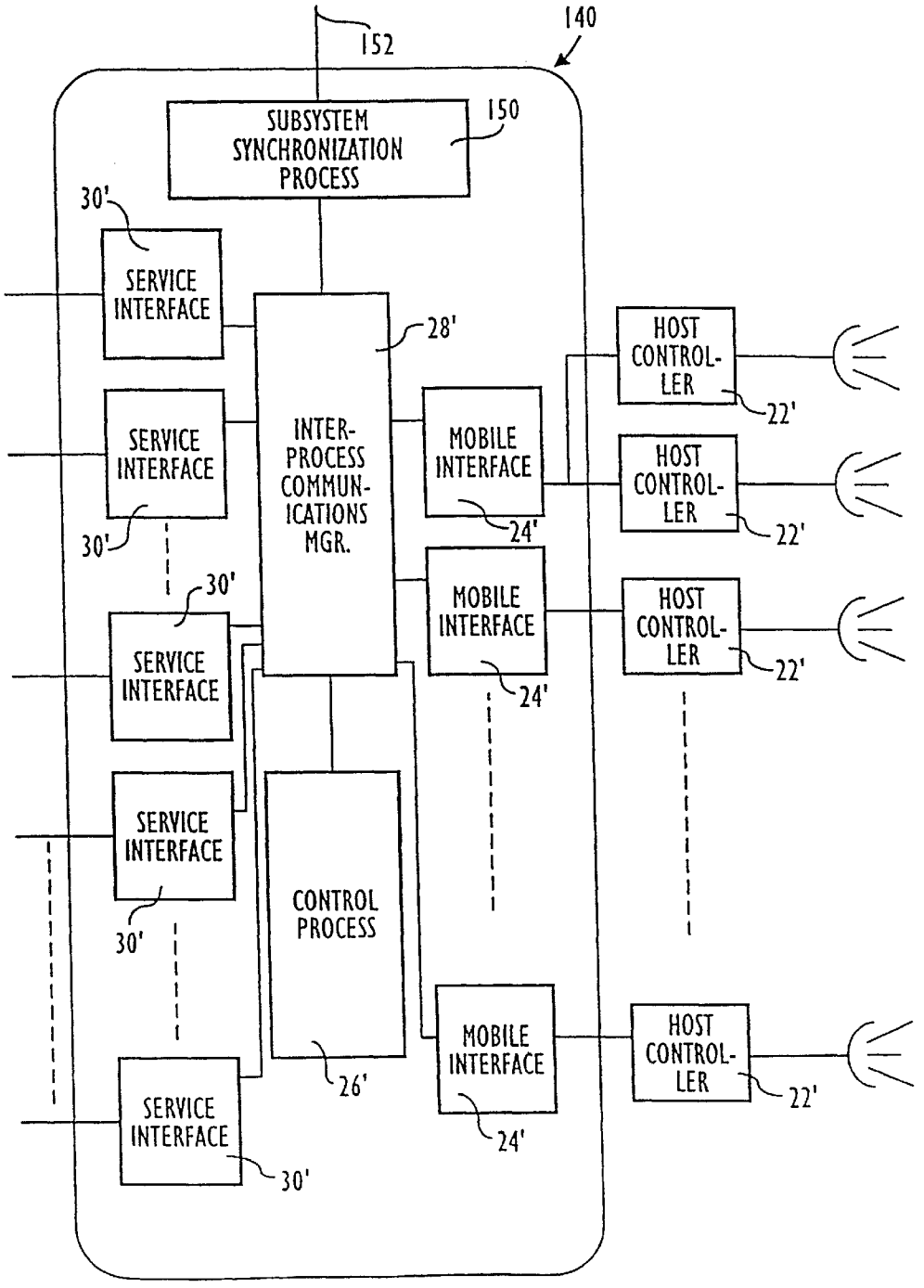

140
152
SUBSYSTEM SYNCHRONIZATION PROCESS
150
30'
SERVICE INTERFACE
28'
INTER-PROCESS COMMUN-ICATIONS MGR.
MOBILE INTERFACE
24'
HOST CONTROL-LER
22'
CONTROL PROCESS
26'

FIG 28

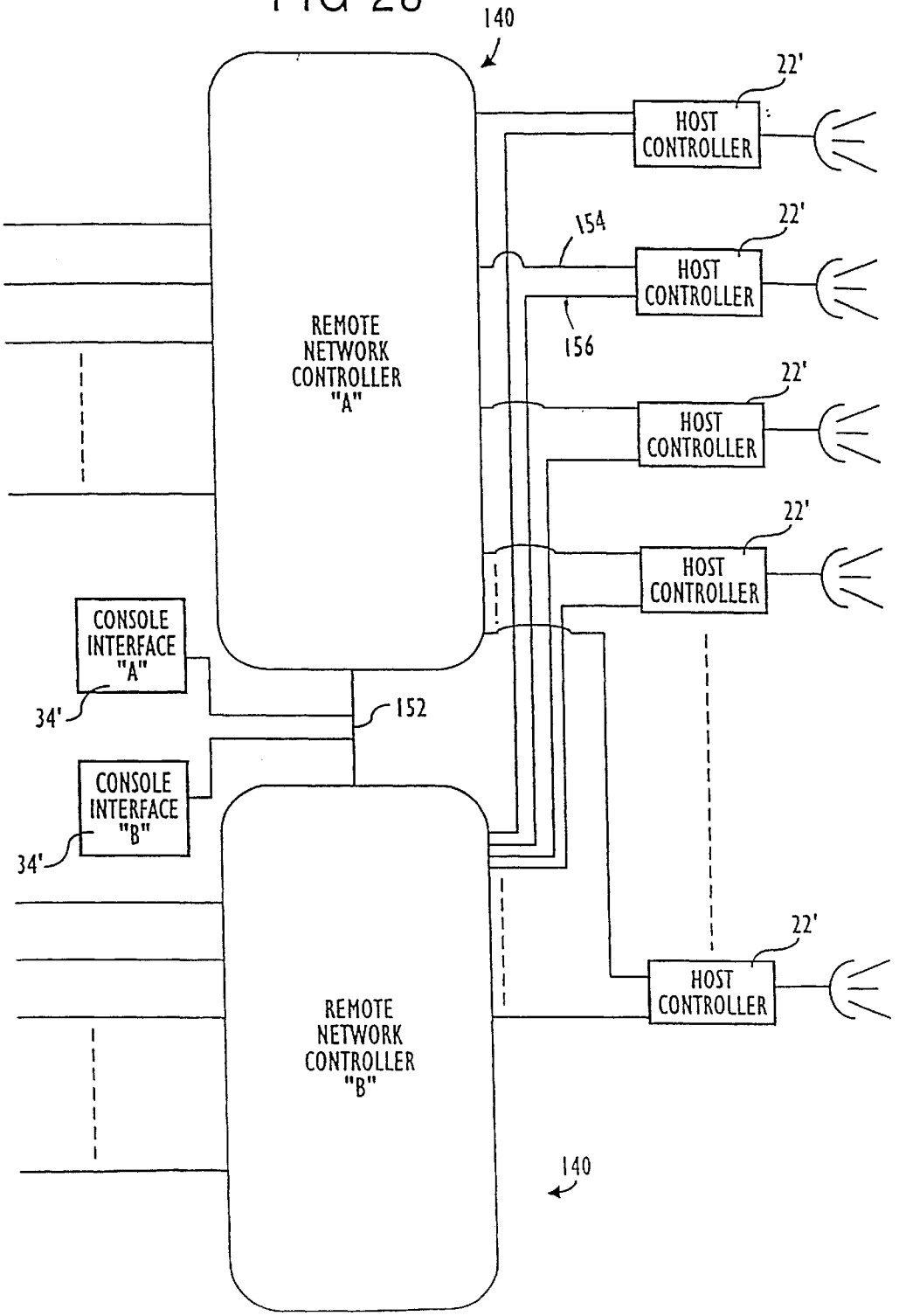
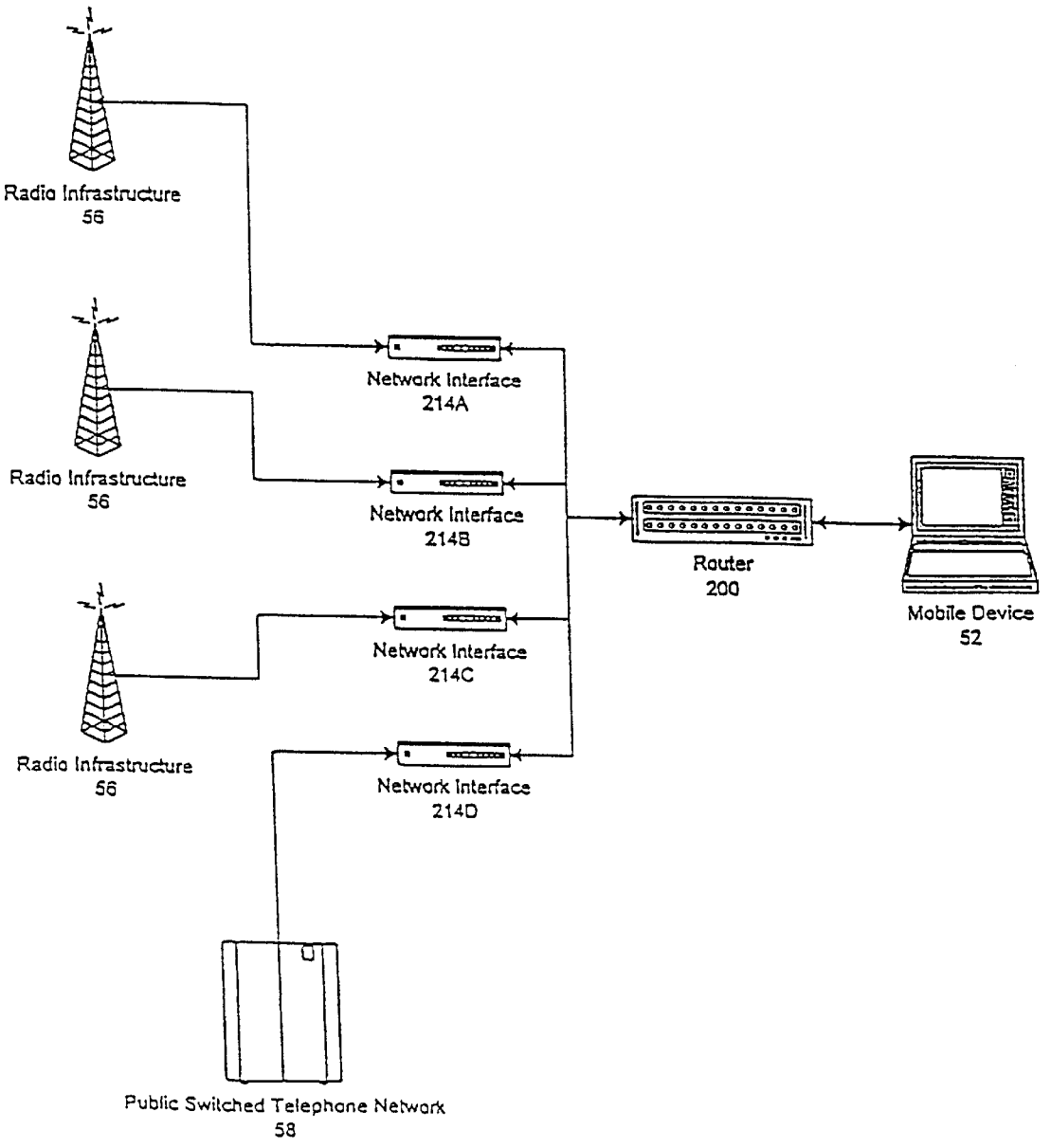

140
22'
HOST CONTROLLER
154
156
REMOTE NETWORK CONTROLLER "A"
CONSOLE INTERFACE "A"
34'
152
CONSOLE INTERFACE "B"
REMOTE NETWORK CONTROLLER "B"

Fig. 29


Radio Infrastructure
56
Radio Infrastructure
56
Radio Infrastructure
56
Network Interface
214A
Network Interface
214B
Network Interface
214C
Network Interface
214D
Router
200
Mobile Device
52
Public Switched Telephone Network
58

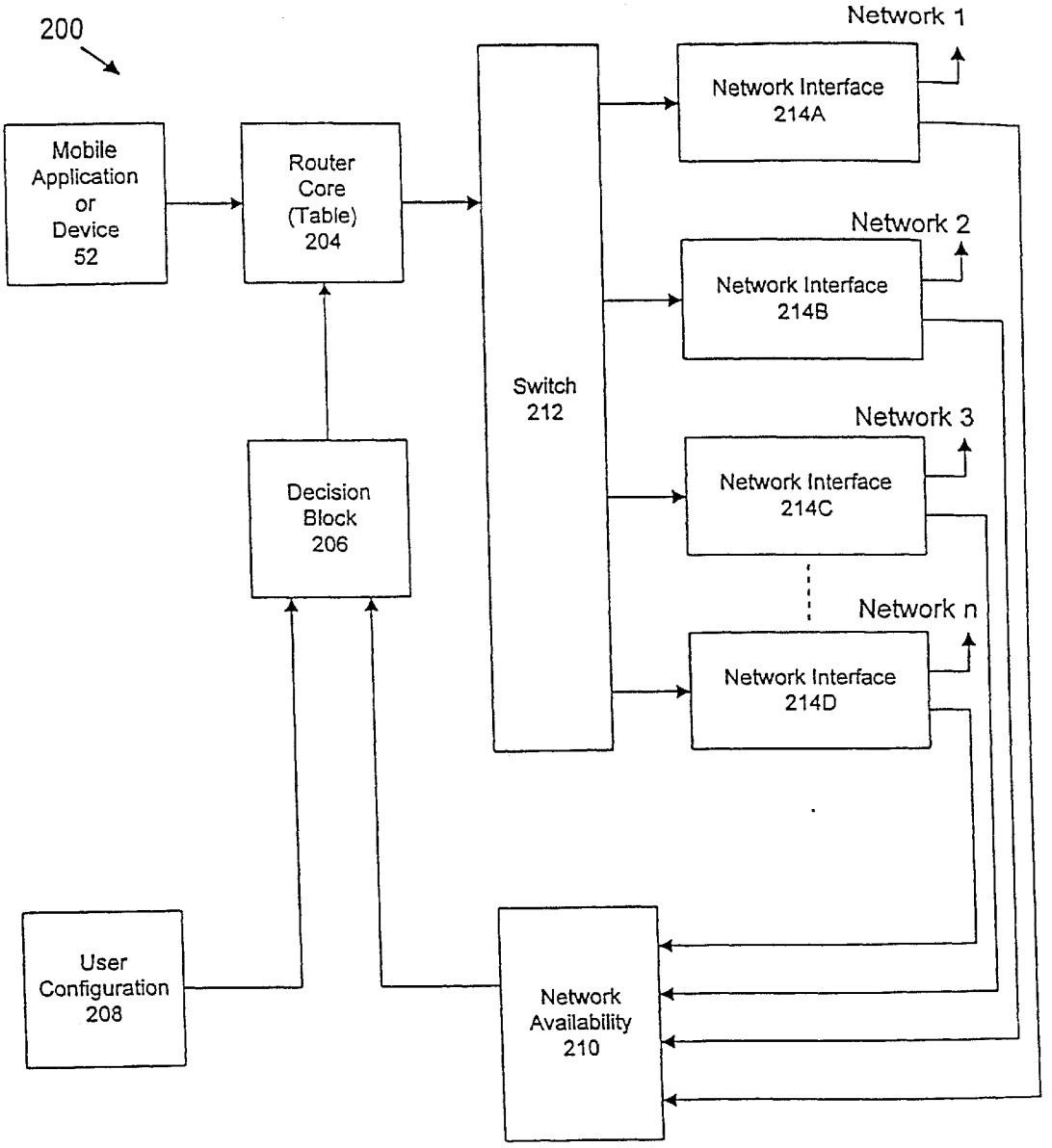
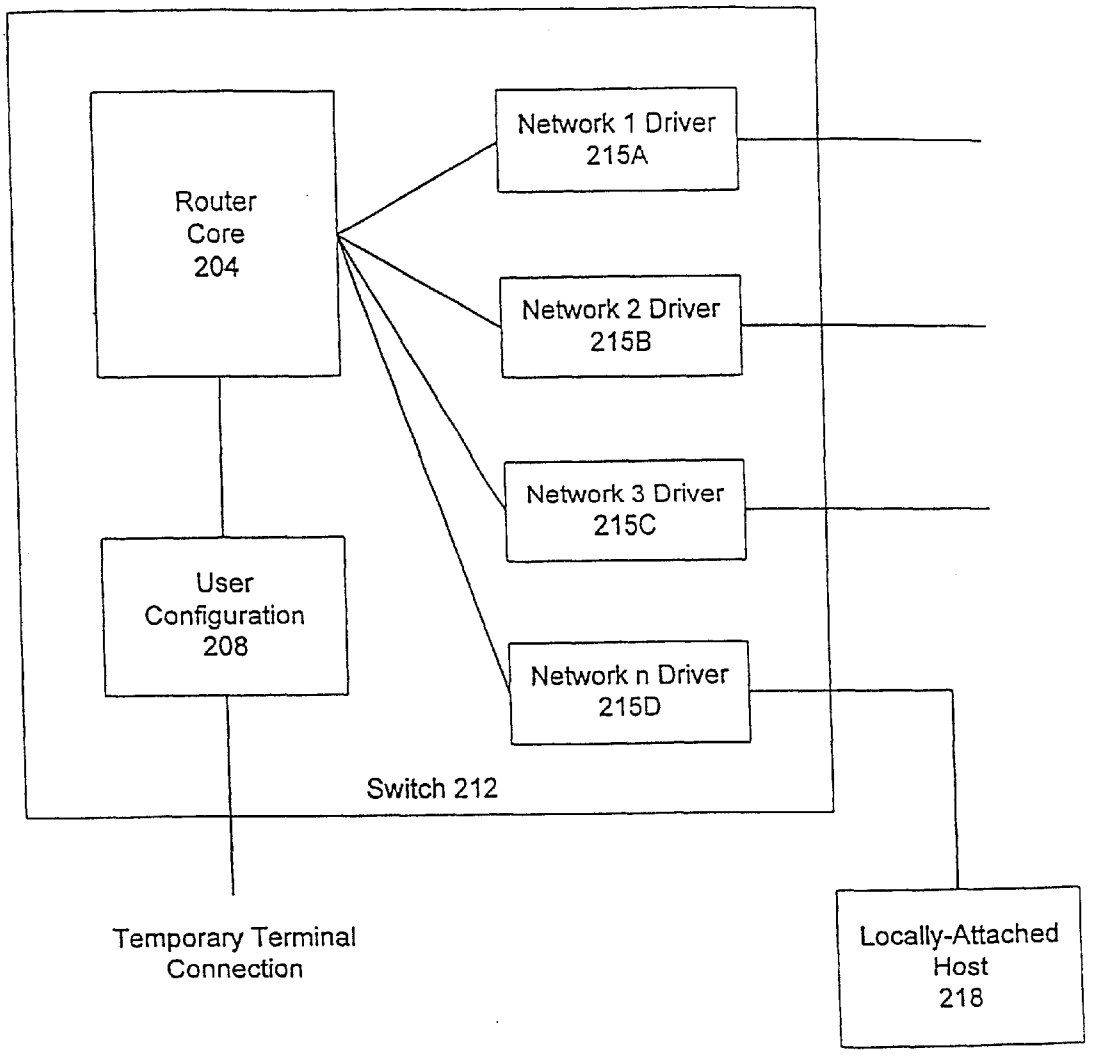

200
Mobile Application or Device 52
Router Core (Table) 204
Switch 212
Network 1
Network Interface 214A
Network 2
Network Interface 214B
Network 3
Network Interface 214C
Network n
Network Interface 214D
Decision Block 206
User Configuration 208
Network Availability 210

FIG. 30

FIG. 31


Router
Core
204
Network 1 Driver
215A
Network 2 Driver
215B
Network 3 Driver
215C
Network n Driver
215D
User
Configuration
208
Switch 212
Temporary Terminal
Connection
Locally-Attached
Host
218

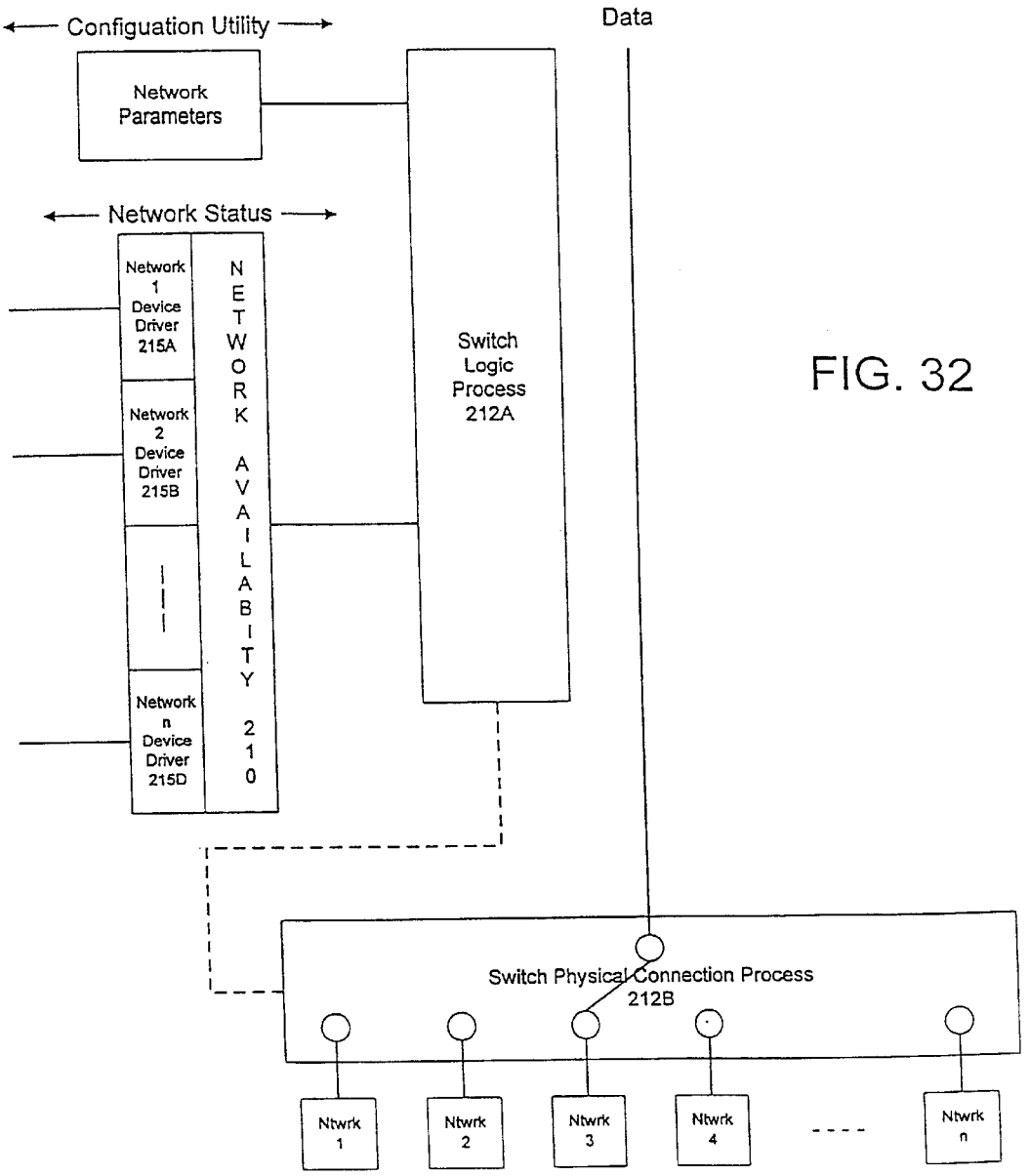

Configuation Utility
Data
Network Parameters
Network Status
Network 1 Device Driver 215A
Network 2 Device Driver 215B
Network n Device Driver 215D
NETWORK AVAILABITY 210
Switch Logic Process 212A
Switch Physical Connection Process 212B
Ntwrk 1
Ntwrk 2
Ntwrk 3
Ntwrk 4
Ntwrk n

FIG. 32

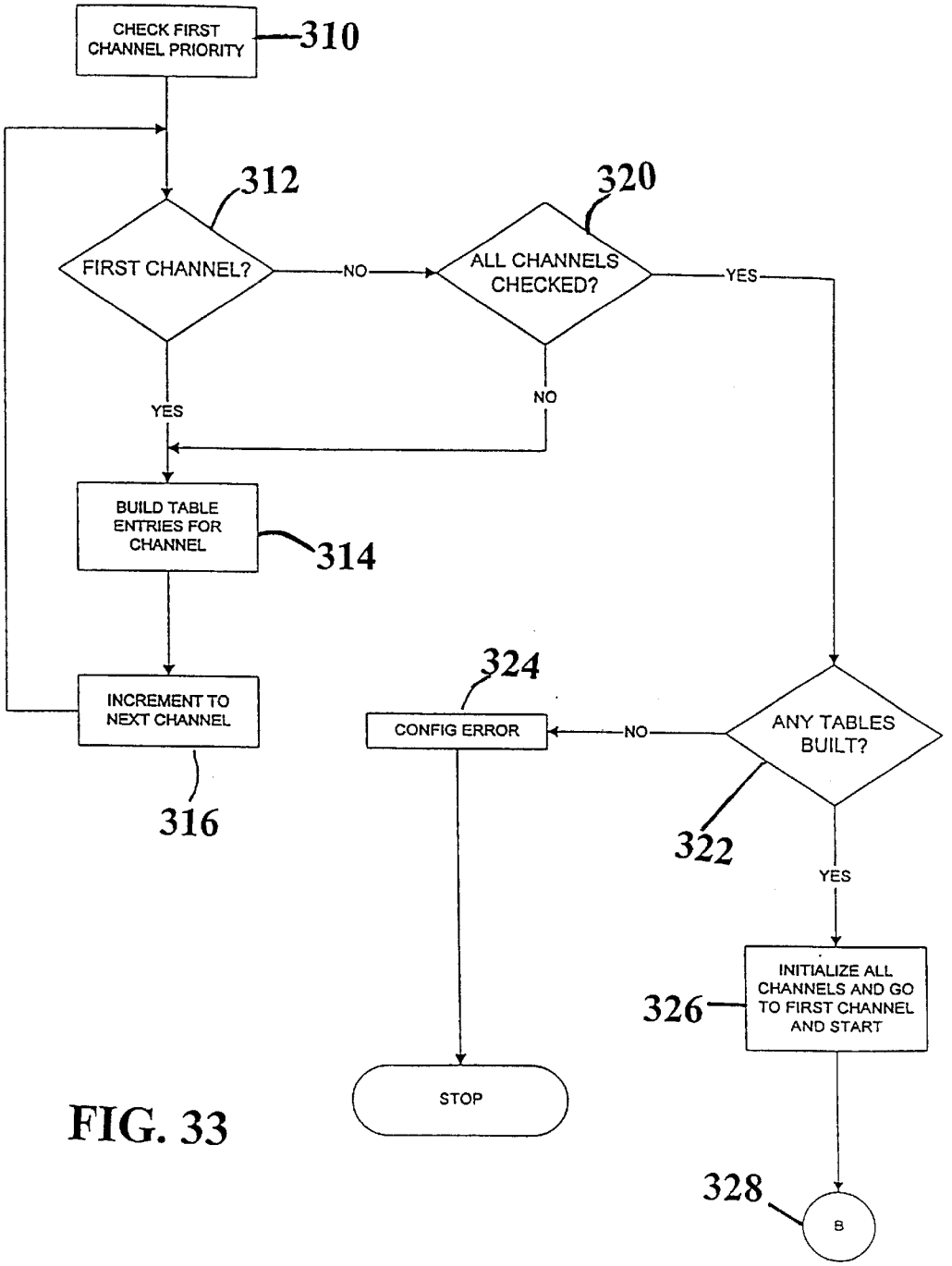

CHECK FIRST CHANNEL PRIORITY
310
312
FIRST CHANNEL?
NO
320
ALL CHANNELS CHECKED?
YES
YES
NO
BUILD TABLE ENTRIES FOR CHANNEL
314
INCREMENT TO NEXT CHANNEL
316
324
CONFIG ERROR
NO
ANY TABLES BUILT?
322
YES
INITIALIZE ALL CHANNELS AND GO TO FIRST CHANNEL AND START
326
STOP
328
B

FIG. 33

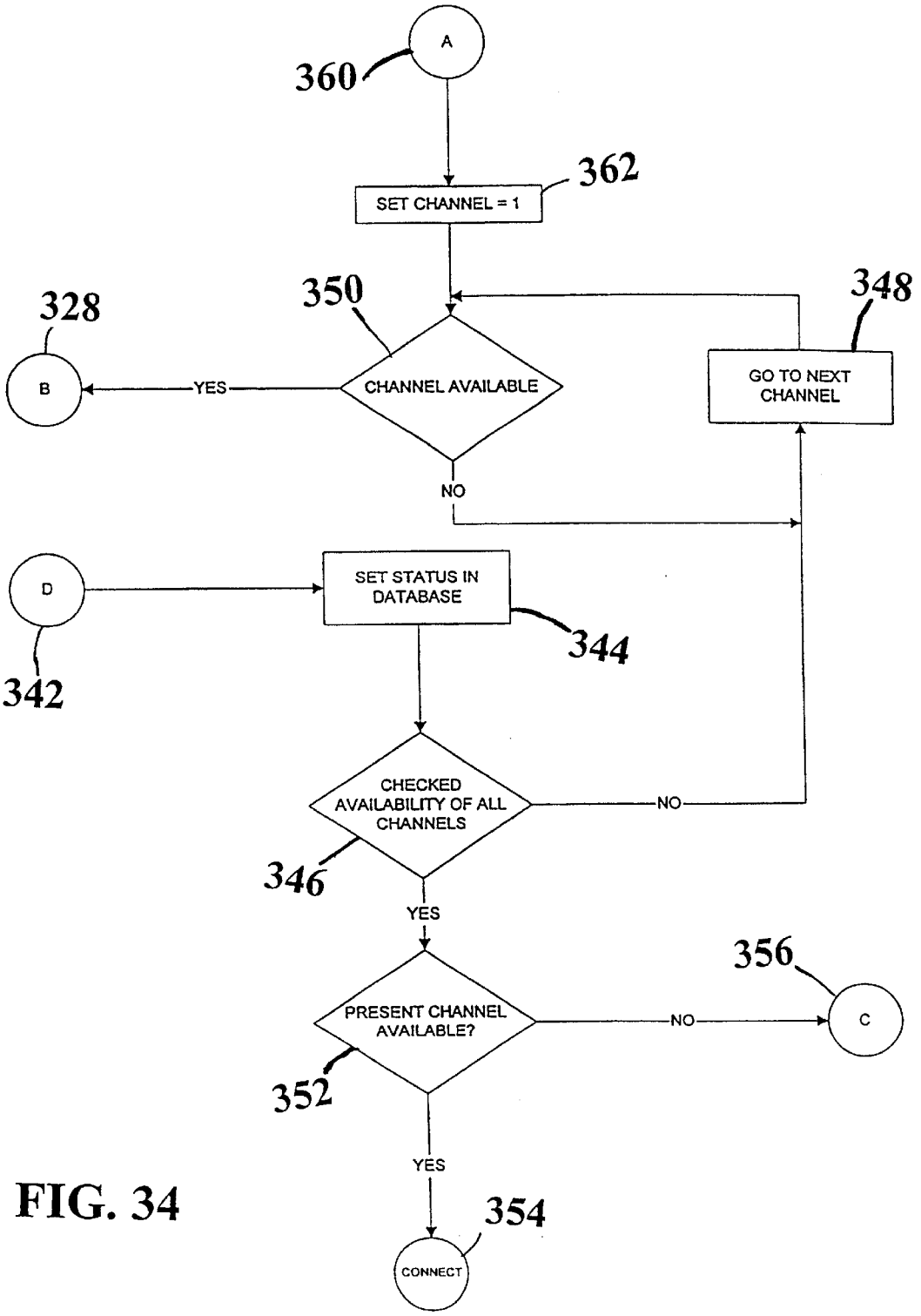

A
360
SET CHANNEL = 1
362
328
350
348
B
YES
CHANNEL AVAILABLE
GO TO NEXT CHANNEL
NO
D
SET STATUS IN DATABASE
344
342
CHECKED AVAILABILITY OF ALL CHANNELS
NO
346
YES
356
PRESENT CHANNEL AVAILABLE?
NO
C
352
YES
354
CONNECT

FIG. 34

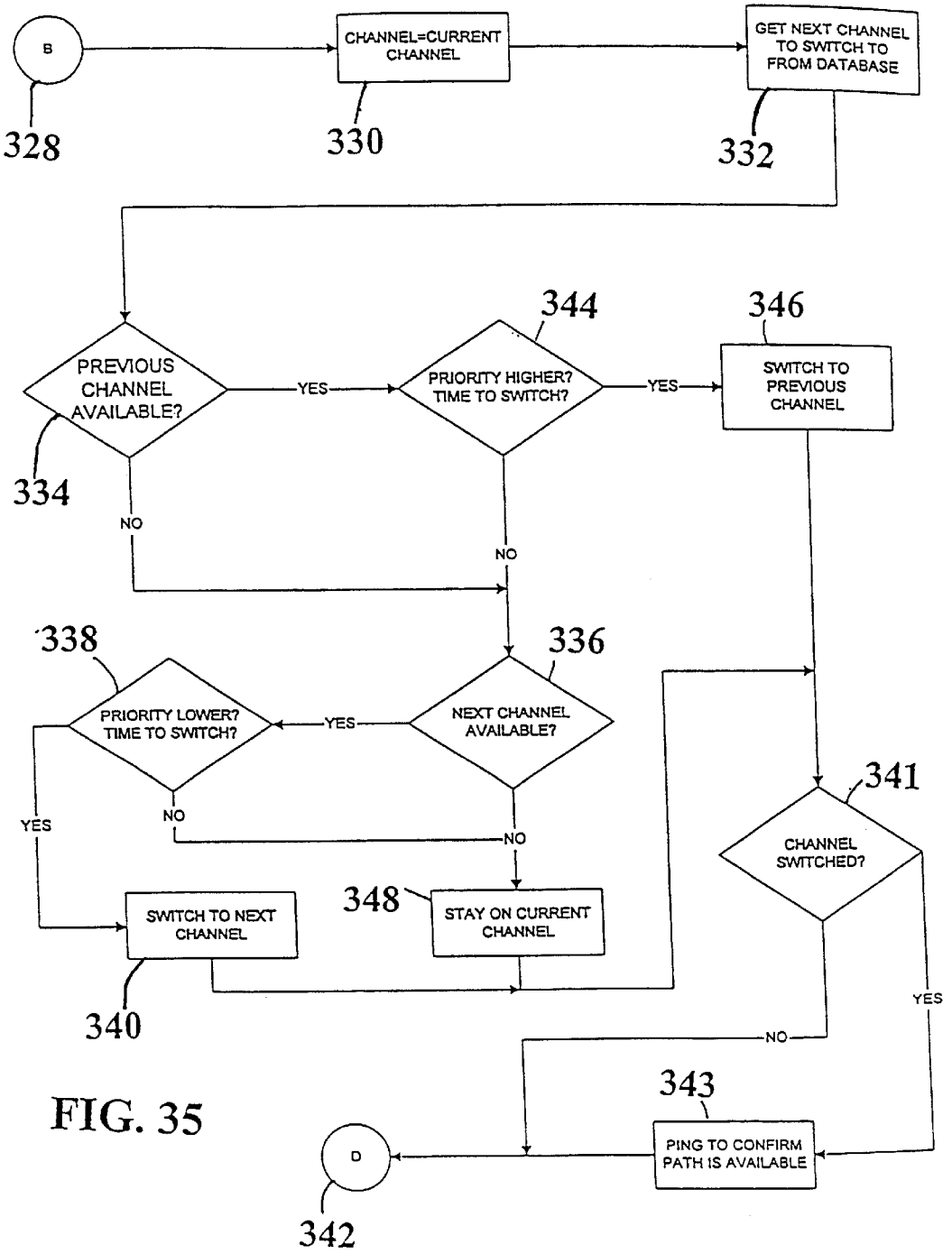

B
328
CHANNEL=CURRENT CHANNEL
330
GET NEXT CHANNEL TO SWITCH TO FROM DATABASE
332
PREVIOUS CHANNEL AVAILABLE?
334
YES
PRIORITY HIGHER? TIME TO SWITCH?
344
YES
SWITCH TO PREVIOUS CHANNEL
346
NO
NO
338
PRIORITY LOWER? TIME TO SWITCH?
YES
NEXT CHANNEL AVAILABLE?
336
NO
NO
YES
SWITCH TO NEXT CHANNEL
340
348
STAY ON CURRENT CHANNEL
341
CHANNEL SWITCHED?
YES
NO
343
PING TO CONFIRM PATH IS AVAILABLE
D
342

FIG. 35

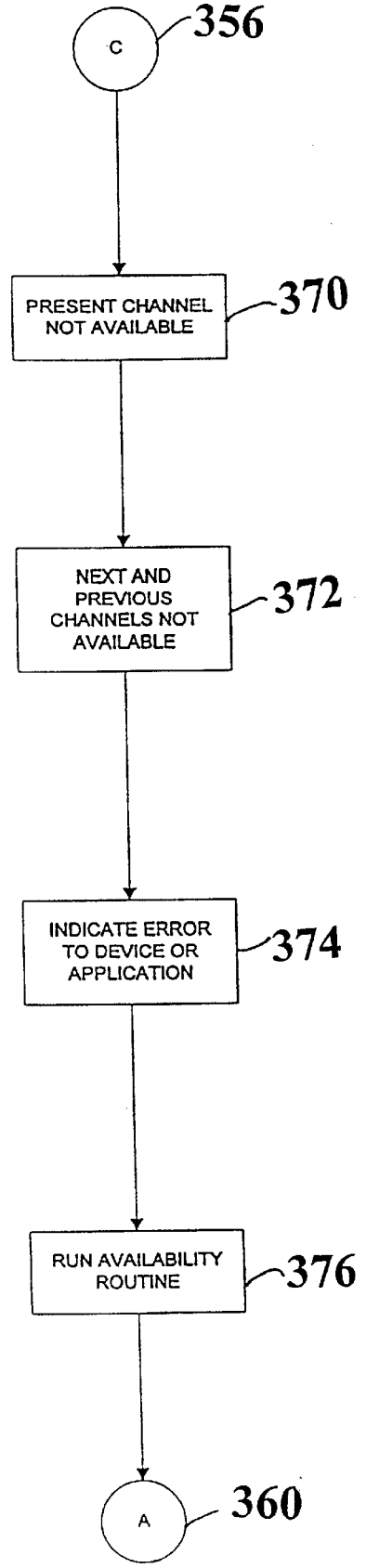
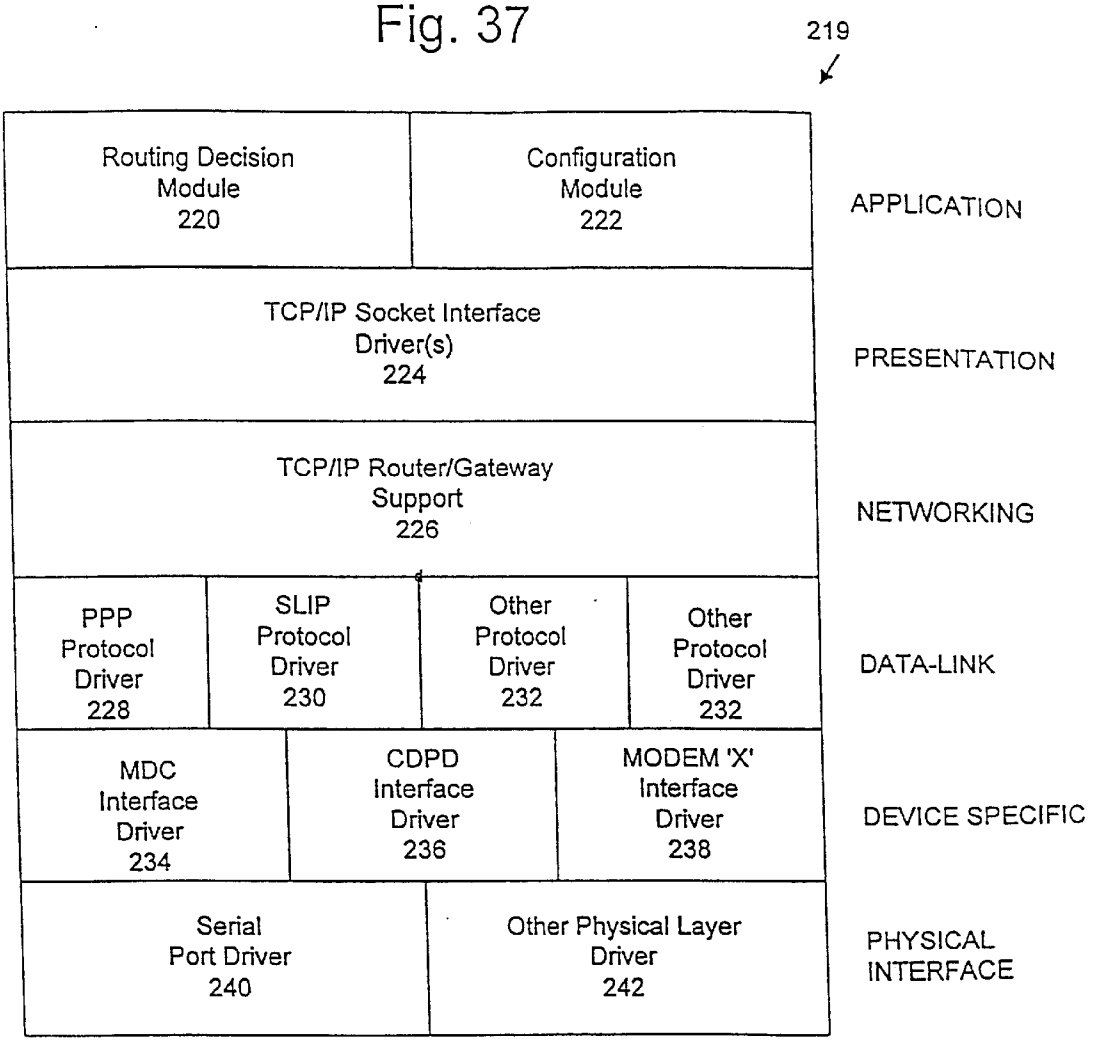

C
356
PRESENT CHANNEL NOT AVAILABLE
370
NEXT AND PREVIOUS CHANNELS NOT AVAILABLE
372
INDICATE ERROR TO DEVICE OR APPLICATION
374
RUN AVAILABILITY ROUTINE
376
A
360

FIG. 36

Fig. 37


219
Routing Decision Module 220
Configuration Module 222
APPLICATION
TCP/IP Socket Interface Driver(s) 224
PRESENTATION
TCP/IP Router/Gateway Support 226
NETWORKING
PPP Protocol Driver 228
SLIP Protocol Driver 230
Other Protocol Driver 232
Other Protocol Driver 232
DATA-LINK
MDC Interface Driver 234
CDPD Interface Driver 236
MODEM 'X' Interface Driver 238
DEVICE SPECIFIC
Serial Port Driver 240
Other Physical Layer Driver 242
PHYSICAL INTERFACE

APPARATUS AND METHOD FOR INTELLIGENT ROUTING OF DATA BETWEEN A REMOTE DEVICE AND A HOST SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation of U.S. application Ser. No. 08/932,532, filed on Sep. 17, 1997, now U.S. Pat. No. 6,418,324, which is the Continuation-In-Part of U.S. application Ser. No. 08/456,860, filed Jun. 1, 1995 (now U.S. Pat. No. 5,717,737), the contents of which are expressly incorporated by reference herein in their entireties.

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to the transportation of data through dissimilar communications media. More particularly, the present invention relates to an apparatus and method for transporting data between a remote mobile or fixed terminal device and a host system over multiple, dissimilar communications media. The communications media over which the data is transported include wireless data links, wired data links or a combination of wireless and wired data links which are selected based upon a set of preference metrics.

2. Background Information

The ability to transport data between mobile and/or fixed terminal devices and host computer systems have been generally available for many years. Networks designed to transport this data currently exist in a wide variety of wireless and wired network architectures. Both apparatus and method exists for transporting data through multiple, similar media types as well as the automatic selection of alternate communication paths based upon a plurality of preference metrics.

Often, when multiple networks are available from a common location such as a vehicle, great benefit may be derived by allowing uniform communications through all available networks. Certain networks may perform better for bulk data transfers where another may perform interactive messaging in an optimal fashion. One network may be preferable because of its low cost but an alternate, more expensive network may be acceptable as a backup if the low-cost network is unavailable.

Other examples include U.S. Pat. No. 5,412,375, to WOOD, which discloses a system for selecting one of a plurality of interfaces to a single wireless communications system in accordance with the capabilities of a subscriber unit and the capabilities of a base unit. A list of air interface capabilities of the subscriber unit and the base unit are compared by a controller to determine a compatible interface. As disclosed in WOOD, the plurality of air interfaces include Analog Mobile Phone System (AMPS), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). While the WOOD system does select from one of a plurality of interfaces which may be applicable for data communication, the routing decision is based on the capabilities of the endpoints rather than the preference metrics of the transporting networks. The endpoint devices, in this case, must be aware of the peculiarities of the wireless environment.

U.S. Pat. No. 5,420,574, to ERICKSON et al., discloses a subscriber unit attached to a trunked mobile radio having a data input. The mobile radio communicates both voice and data message formats over a wireless network to a base station via channels that are allocated by a trunked data controller which is connected to a host network. Channel states and communication parameters are set in accordance with the type of information (e.g., voice or data) that is being transmitted or received. While the ERICKSON et al. system dynamically switches between incompatible message formats without the intervention of the endpoint devices, only a single data path is provided. In addition, the incompatibility of the two alternate paths arises from a difference in message formats rather than the use of independent, incompatible networks.

Further, the transportation of data through alternate, incompatible communications media is a problem that does not have a uniform solution in the art. This problem is exacerbated in wireless communication networks where protocols, timing and other incompatibilities render an otherwise acceptable level of service inadequate. Attempts to provide data links through incompatible networks have suffered from the same obstacles that hindered data communications prior to open standards becoming widely accepted, i.e., proprietary protocols visible to the endpoint terminal devices make the devices inflexible and expensive and the interoperation of similar devices with incompatible networking components is difficult and complex.

Networks may be interconnected by routers which operate at the network level and convey messages between compatible networks. Routers make logical decisions about the pathway through which data is to be directed in the networks based upon a variety of preference metrics. A router is generally implemented as an autonomous device with multiple connections to the networks through which data is to be routed. Routers operate at the network layer and can recognize and manage protocols and multiple connections to networks. Routers usually operate in accordance with the address provided by the particular protocol of the network, and normally provide routing between and through networks utilizing the same network protocol and can route between networks that use different data-link layers, such as Ethernet, Token-Ring, Serial PPP, etc. Another type of router includes two routers loosely-coupled through a protocol-neutral data-link, where the linked routers are considered as a single "virtual" router.

Dissimilar networks may be connected by gateways which are devices that interconnect two or more dissimilar networks. A gateway differs from a router in that the endpoint terminal devices may implement a dissimilar or incompatible protocols. Gateways often perform specific protocol conversions at the layers above the network layer to move data from one type of network to another. In this regard, the Open Systems Interconnection (OSI) model includes seven "layers" to provide communications between heterogeneous (i.e., incompatible) systems. The layers, from lowest to highest, are: the physical layer, the data link layer, the network layer, the transport layer, the session layer, the presentation layer, and the application layer. Each of the layers performs a specific task in transporting data between two or more entities. Such a layered structure is shown in *The TCP/IP Companion*, by Martin R. Arick, Wiley-QED, pp. 18–19.

U.S. patent application Ser. No. 08/456,860, to DOVIAK et al., for example, discloses a system in which a distant mobile or fixed terminal device transports data through a plurality of wireless network to an endpoint which may or may not implement the same network protocol as the distant device. However, while the DOVIAK et al. system is capable transmitting data over a plurality of dissimilar

wireless communications networks, the system does not automatically transmit data through differing ones of a plurality of dissimilar networks in accordance with preference metrics to reach the data-link endpoints. Thus, the system does not automatically provide redundant or alternate pathways through which data may be delivered.

U.S. Pat. No. 5,537,220 to EZUMI et al., discloses a portable facsimile apparatus provided with a capability to communicate over a plurality of communications lines. As disclosed in EZUMI et al., the facsimile machine may communicate over telephone lines or a mobile communication unit. A NCU (controller) is provided within the facsimile machine to discriminate whether the facsimile machine is connected to the telephone line or to the mobile communication unit. The NCU functions to adjust the data rate, and transmitting and receiving signal levels based on which communication system it is communicating. Although this concept may be extended to a generic protocol-neutral data networking environment, the EZUMI et al. system provides for the selection of only one single path to the exclusion of other, possible viable path based solely on which link is plugged into the NCU. Further, the EZUMI et al. system does not switch communication paths within the boundaries of a communication session thereby further limiting its usefulness in a connectionless, packet data environment such as a TCP/IP network.

U.S. Pat. No. 5,602,843, to GRAY, discloses a PBX-based integrated telecommunications system having a wired subsystem connected to wired terminals, and a wireless system for connecting to mobile terminals. A controller is provided which manages base stations and communicates to wireless handsets. When communicating to a handset, the controller determines which base station is in communication with the handset and directs the base station to send packet-based information to that handset. A separate PBX controller is provided to communicate with the wired terminals. The PBX controller includes a proximity sensor to detect wireless handsets such that when a handset is detected in proximity to a wired terminal, messages are forwarded to the wired terminal rather than the wireless handset. While the GRAY system dynamically selects the route to a terminal device based upon a preference metric (wireless proximity), the alternate routing technique does not address transporting data between the same two endpoints. In addition, GRAY provides no means to provide alternate path routing for a terminal device through either the wireless or wired handsets.

U.S. Pat. No. 5,452,471, to LEOPOLD et al., discloses a communication system having a primary and one or more subordinate communication systems. In the illustrated embodiment, the primary communication system is a satellite-base communication system having the widest area of coverage. Each of the satellites within the system defines a cell area which moves as the orbiting satellites move. The secondary and tertiary communications systems are disclosed as terrestrial based, stationary systems having base stations fixed near the surface of the earth (e.g., fixed to a building), where each subordinate system has an increasingly smaller region of coverage. The secondary and tertiary systems include a controller located at a monitoring location within each region. Each of the communications systems includes a link to a central office to enable communications over the public switched telephone network. The LEOPOLD et al. communication systems and mobile subscriber units operate within one frequency spectrum, however, the primary and secondary communication systems operate together by using orthogonal channels to prevent interference. In addition, when communicating with secondary systems, the mobile subscriber unit transmits at a relatively low power such that the primary system will not receive the transmission. The mobile subscriber unit is programmed to utilize the communication system having the smallest area of coverage such that if the subscriber unit has three communications systems available, the subscriber unit will utilize the tertiary communications system (i.e., the system having the smallest area of coverage) based on a designed assumption that the more subordinate the communication system is, the higher the capacity of the system. While the system of LEOPOLD et al. dynamically selects a route based upon a set of preference metrics such that the terminal endpoints are unaware of the routing selection, a common data-link protocol is required throughout all possible associated networks. In addition, the wireless frequencies employed must be derived from a continuous, compatible set of frequencies which prevents the device from selecting among inherently incompatible networks.

Despite the teachings of these prior attempts, users of mobile or fixed wireless data communications are provided with systems of limited capacity and flexibility when routing data through more than one network. In addition, such systems require special hardware and/or software developed for and compatible with the networks, which may require additional training of support personnel and end-users. Further, users of wireless mobile data communication services are provided with only a limited ability to control costs associated with sending and receiving data to and from remote devices, and are limited in their hardware and software design implementations. In previous teachings, the candidate networks must be compatible with one another at either the network or the data-link level. Thus, routing data through inherently incompatible networks such as Cellular Digital Packet Data (CDPD) and Ericsson EDACS is not possible as these are incompatible at both the data-link and network levels. Moreover, known systems do not allow a customer to use existing RF wireless infrastructures, including existing hardware and software, with only minor modifications needed to transport data from a mobile device to a host computer network. In addition, past attempts do not permit wireless data communications in a manner that is transparent to the remote device. Further, prior systems do not provide the flexibility to users such that a plurality of different remote devices may communicate with the wired host network irrespective of the radio infrastructure and transmission protocol employed. Such features, without the above-noted drawbacks, would be highly desirable to provide flexibility and ease of use, and to give users of portable data devices greater control over their hardware and software design.

SUMMARY OF THE INVENTION

In view of the foregoing, the present invention, through one or more of its various aspects, embodiments and/or specific features or sub-components thereof, is thus presented to bring about one or more objects and advantages, such as those specifically noted below.

A general object of the present invention is to provide an apparatus and method for transporting data from a remote, wireless device to a wired network. Another object of the invention is to provide a remote device with an interface to present data to the wired network through RF wireless communication.

More particularly, an object of the present invention is to provide an apparatus that resides between an existing wired

communications network and an existing radio-frequency network to provide a wireless RF connection between a remote device and the wired network.

Another object of the present invention is to provide an apparatus and method for a completely transparent data path between a remotely located device and an existing wired network using a wireless RF communications link without either the remote device, or the wired network being aware that a wireless RF communications link is being employed.

Still another object of the present invention is to provide an apparatus and method for a completely transparent data path between a remotely located device and an existing wired network through a plurality of different wireless RF communications link protocols and a plurality of different wired networks protocols selected by the user.

Still another object of the present invention is to provide an apparatus which functions as a protocol-appropriate communications controller and makes remote devices indistinguishable from locally attached devices to a wired network.

According to one aspect of the present invention, an apparatus for transporting data between a remote device and a host communication network using a wireless communications link is provided. The apparatus comprises a mobile data controller connected to the remote device and the wireless communications link. The mobile data controller comprises a remote data conversion means for converting data to be transported between the remote device and the host communication network. The remote data conversion means converts the transported data between a remote device transmission format utilized by the remote device and a wireless link transmission format utilized by the wireless communications link.

The apparatus also comprises a network interface means for interfacing the host communication network with the wireless communications link. The network interface means comprises a wireless link conversion means for converting the transported data between the wireless link transmission format and a network interface format utilized by the network interface means; and a host network conversion means for converting the transported data between the network interface format and a host network format utilized by the host communication network.

The apparatus further comprises a means for transporting the transported data over the wireless communication in accordance with the wireless link transmission format, the wireless link transmission format and the host network format being incompatible. According to another aspect of the present invention, the network interface means comprises a remote network controller that logically resides on the host communication network and performs the functions of a network communication controller.

According to another aspect of the present invention, the apparatus for transporting data further comprises a plurality of network interface means connected by a local network and a synchronization means for synchronizing the transfer of information between the network interface means, the information comprising routing tables and health and status information.

According to the present invention a method of transporting data from a mobile device to a host network is provided. The remote device and a wireless communications link are connected by a mobile data controller, and the host communication network and the wireless communications link being interfaced by a network interface device.

The method includes the steps of: converting, at the mobile data controller, data to be transported between the remote device and the host communication network, the converting step converting the transported data between a remote device transmission format utilized by the remote device and a wireless link transmission format utilized by the wireless communications link; transporting the transported data over the wireless communications link in accordance with the wireless link transmission format; receiving, at the network interface device, the transport data from the wireless communications link; converting, at the network interface device, the transported data between the wireless link transmission format and a network interface format utilized by the network interface device, the wireless link transmission format and the host network format being incompatible; further converting, at the network interface device, the transported data between the network interface format and a host network format utilized by the host communication network; and forwarding the transported data to the host communication network in accordance with the host network format.

In a preferred embodiment, the transportation step further comprises determining wireless communications link selection criteria; dynamically selecting a wireless communications link from a plurality of incompatible wireless communications links in accordance with the selection criteria; and switching to the selected wireless communications link. Afterwards, the following steps are continuously repeated: dynamically selecting a next wireless communications link from the plurality of incompatible networks in accordance with the selection criteria; determining whether to switch wireless communications links; and switching to the next wireless communications link in response to a result of the determination.

According to another aspect of the present invention, an apparatus for transporting data over a plurality of incompatible networks between a first device and a second device is provided. The apparatus comprises a system for determining network selection criteria. In addition, the apparatus comprises a selection system for dynamically selecting a network from the plurality of incompatible networks in accordance with the network selection criteria and a switching system for switching to the selected network to use for data transport.

According to another aspect of the present invention, the apparatus transports data via a plurality of protocols over a plurality of incompatible networks in which the transportation of data is transparent to the first and second devices and to an end user. The protocols may include but are not limited to Internet Protocol (IP) and transparent protocol.

According to another aspect of the present invention, the apparatus for transporting data further comprises a system interfacing protocolized data into a plurality of incompatible networks using different protocols.

According to another aspect of the present invention, the switching system switches networks during the time between the transport of consecutive data packets.

According to another aspect of the present invention, the system for determining network selection criteria uses two classes of parameters to determine the next network to use for transport of data.

According to another aspect of the present invention, the selection system further determines a next network to switch to from the plurality of incompatible networks in accordance with the network selection criteria, when the selected network becomes unavailable. In addition, a monitoring system is provided which monitors the availability of the incompatible networks to determine whether the next network is available for data transport.

According to yet another aspect, a method is provided for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information. The method includes maintaining a priority of each wireless network. The priorities indicate a most preferred path. The method also includes determining availability of each wireless network based upon status information associated with each wireless network. The method also includes indicating a current most preferred network from the wireless networks determined to be available, the indication being based upon the network priorities. The method further includes switching from a current network, which is dissimilar from the current most preferred network, to the current most preferred network during a transmission. At least one of the current network and current most preferred network is time continuous. The method also includes remaining connected to the current network for a period of time after switching to the current most preferred network.

In another aspect, a computer readable medium storing a program is provided for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information. The medium includes a priority code segment that maintains a priority of each wireless network. The priorities indicate a most preferred path. The method includes an availability code segment that determines availability of each wireless network based upon status information associated with each wireless network; and an indicating code segment that indicates a current most preferred network from the wireless networks determined to be available. The indication is based upon the network priorities. The medium further includes a switching code segment that switches from a current network, which is dissimilar at a link layer from the current most preferred network, to the current most preferred network during a transmission while remaining connected to the current network for a period of time after switching to the current most preferred network.

In yet another aspect, a router is provided for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information. The router includes a priority system that maintains a priority of each wireless network, the priorities indicating a most preferred path. The router also includes multiple transmitters, each transmitter operating with one of the wireless networks. The router further includes a determining system that determines availability of each wireless network based upon status information associated with each wireless network, and an indicator that indicates a current most preferred network from the wireless networks determined to be available. The indication is based upon the network priorities. The router also includes a switch that switches from a current network, which is dissimilar from the current most preferred network, to the current most preferred network during a transmission while remaining connected to the current network for a period of time after switching to the current most preferred network.

In still another aspect, a computer readable medium is provided for storing a program for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information. The medium includes an availability code segment that ascertains availability of at least two of the wireless networks based upon the status information; and a determining code segment that determines whether to switch between networks when at least two networks are available, in response to a user configuration and each network's speed. The medium also includes a switching code segment that switches from a first available network to a second available network, which is dissimilar at a link layer from the first available network, during a transmission while remaining connected to both the first network and the second network for a period of time.

In yet another aspect, a method is provided for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information. The method includes ascertaining availability of at least two of the wireless networks based upon the status information; and determining whether to switch between networks when at least two networks are available, in response to a user configuration and each network's speed. The method also includes switching from a first available network to a second available network during a transmission, the second network being dissimilar from the first network; and stopping transmitting over the first available network after switching to the second available network. The method further includes remaining connected to the first network for a period of time after switching to the second network.

In another aspect, a method is provided for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information. The method includes determining availability of at least two of the wireless networks; and identifying a current most preferred network, when multiple wireless networks are determined to be available. The identification is based upon a speed of each available network. The method also includes switching from a current network, which is dissimilar at a link layer from the current most preferred network, to the current most preferred network during a transmission; and remaining connected to the current network for a period of time after switching to the current most preferred network.

In still another aspect, a mobile system includes a local device and a server. The local device may be a database server application, and resides on a local area network. The server is connected to the local device via the local area network, and connected to multiple incompatible wireless networks. The system also includes a mobile device connected to the incompatible wireless networks. The mobile device is associated with multiple transmitters, each transmitter operating with one of the dissimilar networks. The mobile device includes a client application that enables a remote user to send and retrieve data from the database server application via the server. The mobile device sends data to the database server application via at least two of the incompatible wireless networks while switching between the at least two incompatible wireless networks, and remains connected to the at least two incompatible wireless networks for a period of time after switching.

In still another aspect, a method is provided for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information. The multiple wireless networks are simultaneously in coverage and each associated with a transmitter. The method includes maintaining a priority of each wireless network, the priorities indicating a most preferred network. The method further includes determining availability of each wireless network based upon status information associated with each wireless network, including determining if a previous network is available, and determining if a next network is available when the previous network is not available or is a lower priority than a current network. The method also includes indicating a current most preferred network from the wireless networks determined to be available. The indication is based upon the network priorities. The current most preferred network is the previous network when the previous network is available and the previous network is a higher

priority than the current network, which is dissimilar at the link layer from the current most preferred network. The method further includes switching from the current network to the current most preferred network, which has a higher priority, during a transmission when the higher priority network becomes available. The method also includes interrupting transmitting over the current network after switching to the current most preferred network, and remaining connected to the current network for a period of time after switching to the current most preferred network.

In another aspect, a computer readable medium is provided for storing a program that enables switching between dissimilar wireless networks, at least one of the dissimilar networks being a GSM network connected between a server and a mobile device. The server is connected to a local device via a local area network. The medium includes an availability code segment that periodically checks the status of the dissimilar networks, including the GSM network; and a transmitting code segment. The transmitting code segment transmits an updated job status via the server to the local device to inform a dispatcher of locations of field service personnel. The updated status is transmitted via at least two of the dissimilar networks while switching between the at least two dissimilar networks when a second of the dissimilar networks is faster than a first of the dissimilar networks and when the second network has a higher priority than the first network. The mobile remains connected to the at least two dissimilar networks for a period of time after switching. The job status is updated by an application that also retrieves a list of jobs to be performed by field service personnel from the local device.

The above-listed and other objects, features and advantages of the present invention will be more fully set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is further described in the detailed description which follows, by reference to the noted plurality of drawings by way of non-limiting examples of preferred embodiments of the present invention, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:

FIG. **1** illustrates a general overview of a remote network controller and mobile data controller in accordance with an aspect of the present invention;

FIG. **2** illustrates a block diagram of the basic components of the remote network controller and mobile data controller of the present invention;

FIG. **3** is a high-level flow chart, according to the present invention, of the outbound data from a wired communication network to a remote device;

FIG. **4** is a high-level flow chart, according to the present invention, illustrating the flow of inbound data from a remote device to a wired communication network;

FIG. **5** illustrates a block diagram of the components of a mobile interface in accordance with the present invention;

FIG. **6** is a flow chart of the processing of an event handler and multithreading dispatcher associated with the mobile interface of the present invention;

FIG. **7** is a flow chart for indicating the process flow of a process initialization module associated with the mobile interface of the present invention;

FIG. **8** is a flow chart for indicating the processing of a mobile session manager associated with the mobile interface of the present invention;

FIG. **9** is a flow chart of the processing steps for an inbound data event handler associated with the mobile interface of the present invention;

FIG. **10** is a flow chart of the processing steps for an outbound data event handler associated with the mobile interface of the present invention;

FIG. **11** is a flow chart of the processing steps for a process termination module associated with the mobile interface of the present invention;

FIG. **12** is a flow chart of the processes associated with a host data controller interface module associated with the mobile interface of the present invention;

FIG. **13** is a block diagram of the various components of a host data controller in accordance with an aspect of the present invention;

FIG. **14** is a block diagram of the components comprising a service interface according to the present invention;

FIG. **15** is a flow chart of the processing of an event handler and multithreading dispatcher associated with the service interface of the invention;

FIG. **16** is a flow chart describing the process flow of a process initialization module associated with the service interface of the invention;

FIG. **17** is a flow chart of the processing steps for an inbound data event handler associated with the service interface of the present invention;

FIG. **18** is a flow chart of the processing steps for an outbound data event handler associated with the service interface of the present invention;

FIG. **19** is a flow chart of the processing steps for a process termination module associated with the service interface of the present invention;

FIGS. **20**, **21**, **22**, **23**A, **23**B and **24** are flow charts of the various processes associated with a wired communication network interface module associated with the service interface in accordance with the present invention;

FIG. **25** is a block diagram of the various components of a mobile data controller of the present invention;

FIG. **26** is a block diagram of the various components of a remote gateway according to another aspect of the present invention;

FIGS. **27** and **28** illustrate a block diagram of a remote network controller in accordance with still another aspect of the present invention, in which a subsystem synchronization process module is utilized;

FIG. **29** illustrates a general overview of another embodiment of the present invention which includes a mobile router in accordance with an aspect of the present invention;

FIG. **30** illustrates a schematic block diagram of the mobile router in accordance with an aspect of the present invention;

FIG. **31** is an illustration of a block diagram of the functional components of the router in accordance with an aspect of the present invention;

FIG. **32** is an illustration of a block diagram of the switch within the router according to the present invention;

FIG. **33** is an illustration of a flow chart of the processing steps used by the router to initialize and build tables stored in the Router in accordance with an aspect of the present invention;

FIG. **34** is a flow chart of the processing steps used by the router for checking availability of each network interface in accordance with an aspect of the present invention;

FIG. **35** is a flow chart of the processing steps used by the router to account the availability of the channels and the user's configuration in order to decide which channel to use for transporting data in accordance with an aspect of the present invention;

FIG. **36** is a flow chart of the processing steps used by the router for an error handler in accordance with an aspect of the present invention; and

FIG. **37** is an illustration of the software architecture of the Router in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Referring now to the accompanying drawings, FIG. **1** illustrates a general overview of a remote network controller and a mobile data controller in accordance with an aspect of the present invention. In FIG. **1**, a wired communication network **10** is shown as a host network system having communications controllers **15** and locally-attached devices **12**. The wired communication network **10** may be, for example, a Token Ring network or an Ethernet Local Area Network (LAN). The locally-attached devices **12** may include a personal computer, a workstation, a printer or network server, and reside at a plurality of dispersed locations. According to the present invention, a remote network controller **20** may also be provided which logically resides on the wired communication network **10** and acts as a protocol-appropriate communications controller to send and receive data to and from the communications network **10** and one or more remote or mobile devices **52**. For purposes of illustration, only one of the remote devices **52** is shown in FIG. **1**.

Remote devices **52** communicate via a mobile data controller **54** and a wireless radio-frequency (RF) communications link **55** created by the user's radio infrastructure **56** to the remote network controller **20**. The mobile data controller **54** may convert asynchronous data from the remote device **52** into an appropriate protocol format of the radio infrastructure **56**. In accordance with an aspect of the present invention, the remote devices **52**, although not physically connected to the wired communication network **10**, are logically connected to the wired communication network **10** through the radio infrastructure **56** and the remote network controller **20** and are indistinguishable from locally-attached devices **12**. The remote devices **52** may be, for example, a laptop computer, personal digital assistant (PDA), a credit card reader, or a global positioning system (GPS) receiver. The radio infrastructure **56** may comprise a conventional point to point or trunking radio system.

The logical connection created by the remote network controller **20** between the remote device **52** and the wired communication network **10** is "transparent" to the user of the remote device **52**, and to the wired communication network **10**. In accordance with an aspect of the invention, the remote network controller **20** takes data transported by the radio infrastructure **56**, irrespective of the format protocol of the radio infrastructure, and converts the data into a format protocol recognized by the wired network **10**. Similarly, the remote network controller **20** of the present invention takes data from the wired network **10** and converts the data into a format protocol recognized by the radio infrastructure **56**. Accordingly, the user of the remote device **52** does not have to perform any additional steps to send and receive data to and from the wired communication network **10**, and the wired communication network **10** does not have to perform any additional steps to send and receive data to and from the remote device **52**. The user of the remote device **52** interacts with the wired communication network **10** in a similar manner as a user of the locally-attached devices **12**. Similarly, the wired communication network **10** interacts with the remote device **52** in a similar manner as the wired communication network interacts with the locally-attached devices **12**.

Referring now to FIG. **2**, there is illustrated a block diagram of the basic components of the remote network controller **20** of the present invention. Each component of the remote network controller **20** will be generally described for introductory purposes and will later be described in greater detail below with reference to the accompanying drawings. The various components of the host data controller **22** and the mobile data controller **54** will also be discussed hereinafter with reference to FIGS. **13** and **25**, respectively.

As shown in FIG. **2**, the remote network controller **20** may comprise a service interface **30**, a mobile interface **24**, an interprocess communication manager **28**, a control process module **26**, and a console interface **34**. The remote network controller may be implemented through a collection of software program modules and hardware components working cooperatively. The remote network controller **20** itself may run on a standard platform, such as a personal computer (PC) equipped with a commercially available processor or multi-processor, e.g., an Intel or Motorola based processor or multi-processor, and a commercially available operating system, such as an MS-DOS or UNIX based operating system. The remote network controller **20** may also contain an Ethernet controller or suitable network controller card depending on the wired communication network **10**. In addition, the remote network controller **20** may include random access memory and physical storage media including hard disk and tape storage devices.

The wired communications network **10** is connected to the remote network controller **20** by the service interface **30**. The service interface **30** handles all network connections. If several wired communications networks **10** are present, one or more service interfaces **30** may be provided to handle wired network connectivity. The service interface **30** connects to an interprocess communication manager **26**. The interprocess communication manager **28** manages all interprocess message routing within the remote network controller **20**. One or more mobile interfaces **24** may also be provided to handle connectivity with the radio infrastructure (s) **56**. Each mobile interface **24** is also connected to the interprocess communication manager **28**. The control process module **26** of the remote network controller **20** is provided to process management functions and data integrity. The control process module **26** is connected to the interprocess communication manager **28** and the console interface **34**. The console interface **34** allows for user configuration and reporting of data.

As further illustrated in FIG. **2**, the remote network controller **20** may be connected to a host data controller **22**. One or more host data controllers **22** may be provided for connecting the remote network controller **20** to specific radio infrastructures **56**, e.g., a Motorola trunked radio. The host data controller **22** may be connected to the mobile interface **24** of the remote network controller **20**.

In the field, the remote device **52** is connected to the mobile data controller **54** which, in turn, is connected to the radio infrastructure **56** for transmitting and receiving data. The mobile data controller **54** is responsible for connecting

the remote device **52** to the radio infrastructure **56** and to provide protocol-independent asynchronous serial data transfer to and from the remote device **52**.

In order to provide transparent data transportation, whereby the network protocols and the protocols of the radio infrastructure **56** are transparent or invisible to the user, inbound asynchronous data from the remote device **52** is collected and transported to the wired communication network **10** in packets over the radio infrastructure **56**. The data is sent using the existing protocols of the radio infrastructure **56**. The remote network controller **20** accepts the data and encapsulates it into the appropriate protocol used by the wired communication network **10**. The data is passed to the wired communication network **10** in a similar fashion for passing data from any of the other locally-attached devices **12**. Similarly, outbound data to the remote device **52** from the wired communication network **10** is removed from the network protocol by the remote network controller **20**. The remote network controller then encapsulates the data into the appropriate protocol associated with the radio infrastructure **56** and sends the data over the radio infrastructure **56** to the mobile data controller **54**. Upon receipt of the data, the mobile data controller **54** removes the data from the radio infrastructure protocol and asynchronously sends the data to the remote device **52**.

In accordance with the present invention, multiple wired networks **10** with different protocols may be linked to multiple RF environments in any combination by incorporating the remote network controller and mobile data controller of the present invention.

FIG. **3** is a high-level flow chart for transporting outbound data from the wired communication network **10** to the remote device **52**. As shown in FIG. **3**, when data is to be sent to the remote device **52**, the service interface **30** of the remote network controller **20** accepts data from the wired communication network **10** at step **500**. The service interface **30** then converts the data from the protocol used by the wired communication network **10** and encapsulates it into an internal protocol used by the remote network controller **20** at step **502**. In addition, the service interface **30** may receive routing information from the wired communication network **10** as to what remote device **52** the data is to be passed, e.g., a network address or device identifier of the remote device **52**.

At step **504**, the service interface **30** forwards the data to the interprocess communication manager **28**. The interprocess communication manager **28** accepts the data at step **506** and, at step **508**, places the data in a queue for the appropriate destination mobile interface **24**. The destination mobile interface **24** may depend on the radio infrastructure **56** employed by the user. The outbound data that is to be passed from the interprocess communications manager **28** to the mobile interface **24** may be encapsulated in an internal protocol of the remote network controller **20**, along with routing information to specify the remote device **52** to which the data is to be sent. At step **510**, the interprocess communication manager **28** notifies the mobile interface **24** that the data to be sent to the remote device **52** is queued for the mobile interface. The particular mobile interface **24** that the data is queued for depends on the particular radio infrastructure **56** employed to communicate with the destination remote device **52**. At step **512**, the mobile interface **24** requests that the queued data be sent from the interprocess communication manager **28**. The mobile interface **24** may request data when it is free to send the data to a destination remote device **52** and not handling another process. At step **514**, the mobile interface **24** accepts the queued data from the interprocess communication manager **28**. Thereafter, at step **516**, the mobile interface **24** determines, based on the queued data, the destination node address of the remote device **52** to which the data is to be sent. At step **518**, the mobile interface **24** forwards the data to the appropriate host data controller **22** so that it may be sent over the radio infrastructure **56** at step **520**. According to an aspect of the present invention, the host data controller **22** may receive the data, remove it from the internal protocol and encapsulate the data into a packet determined by the protocol used by the radio infrastructure **56**. The packet of data may be broadcasted over the radio infrastructure **56** so as to enable the host data controller **22** to communicate with multiple mobile data controllers **54** simultaneously. The broadcasted data packet may include the identification of the specific mobile data controller **54** to which the packet is to be delivered, so that only uniquely identified mobile controller(s) may accept the packet.

Referring again to FIG. **3**, at step **522**, the mobile data controller **54** receives the data from the remote radio infrastructure **56** and decodes the data. The data packet, once received by the mobile data controller **54**, is accepted and the data is removed from the packet. At step **524**, the mobile data controller **54** validates the data and, at step **526**, sends an acknowledgment or rejection message to the host data controller **22** via the radio infrastructure **56**. According to the present invention, the remote network controller **20** and the host data controller **22** may be responsible for ensuring the integrity of the data transported over the radio infrastructure. As such, an error detection/retry mechanism may be employed to detect and correct data transmission errors. After the integrity of the data is verified, the mobile data controller **54** at step **528** will forward the data to the remote device **52**. The data may be asynchronously transferred to the remote device **52** through a serial connection.

FIG. **4** is a high-level flow chart illustrating the processing of inbound data from the remote device **52** to the wired communication network **10**. At step **550**, the mobile data controller **54** accepts data from the remote device **52**. At step **552**, the mobile data controller **54** formats and sends the data to the remote network controller **20** via the radio infrastructure **56**, which may comprise a modem. The data may be transmitted using the appropriate protocol of the radio infrastructure **56**. The data may be modulated within the mobile data controller **54** prior to transmission via the radio infrastructure **56**. The mobile data controller **52** may place the data from the remote device **52** into packets to be sent over the radio infrastructure **56**. The packet size can be determined by one of three methods. The first is a maximum packet size. Once an upper limit of data is accumulated, the mobile data controller **54** may send the packet of information to the host data controller **22**. For example, once 256 bytes of data are collected, the data may be sent by the radio infrastructure **56** over the RF communications link **55**. The second method is a maximum time to wait before sending data. In this case the mobile data controller **54** will send a packet after waiting a predetermined period of time, no matter how much data is accumulated. The third method involves the mobile data controller **54** detecting a predefined "end-of-packet" character which causes all accumulated data to be transmitted.

At step **554**, the host data controller **22** receives and decodes the data packet from the protocol of the radio infrastructure **56**. Generally, the data arrives as a packet of a predetermined size. At step **556**, the host data controller **22** validates the data and, thereafter, sends at step **558** an acknowledgment or rejection message to the mobile data

controller **54** based on the validation process. According to an aspect of the present invention, the host data controller **22** may determine if the transmitted data packet is correct, or in error. The host data controller **22** may also determine if the data packet has arrived in the proper sequence, and that the packet is not a duplicate. As discussed above, the inbound data may be removed from the packet and encapsulated in the internal protocol used by the remote network controller **20**. The internal protocol may contain additional information, such as the identification of the mobile data controller **54** which sent the information.

At step **560**, the host data controller **22** forwards the data to the mobile interface **24**. The mobile interface **24** accepts the data from the host data controller **22** at step **562**. The mobile interface **24** validates the address of the source of the data (e.g., the particular mobile data controller **54** or remote device **52**) at step **562**. At step **566**, the mobile interface **24** forwards the data to the interprocess communication manager **28**, which accepts the data at step **568**. The mobile interface may also pass the routing information specifying the remote device **52** from which the data originated. At step **570**, the interprocess communication manager **28** places the data into a queue for the destination service interface **30**. The particular destination service interface **30** will depend upon which wired communication network **10** the data is to be delivered. Included in the information which is passed to the service interface **30** is the destination address (i.e., the communication network **10** to which the data is to be delivered). At step **572**, the service interface **30**, when available to handle data, requests the data from the interprocess communication manager **28**. The service interface **30** accepts the data at step **576** and converts the data into an appropriate form, i.e., protocol, usable by the wired communication network **10** at step **578**. As a result, the data may be passed to the hardware device (e.g., an Ethernet controller) using the protocol required by the wired communication network **10**. This configuration allows any existing network interface card to be used in conjunction with the remote network controller **20**, because the data is placed into the appropriate network protocol by the service interface **30** before it is transmitted to the wired network. At step **580**, the service interface **30** forwards the data to the wired communication network **10**.

The validation process of the outbound data depicted in FIG. **3** and inbound data depicted in FIG. **4** does not depend on the type of wired communication network employed by the user. Through a single validation process performed by the host data controller **22** and the mobile data controller **54** (see steps **524** and **526** in FIG. **3** and steps **556** and **558** in FIG. **4**), the integrity of the data transmitted from the wired communication network **10** to the remote device **52** through the radio infrastructure **56** is ensured. This validation process may include, for example, an error detection and retry mechanism to detect errors and to cause (when necessary) the retransmission of the data.

Referring now to FIG. **5**, there is illustrated a block diagram of the basic components of the mobile interface **24** of the remote network controller **20** of the present invention. As noted above, the mobile interface **24** is responsible for interfacing the remote network controller **20** with the host data controller **22** and the radio infrastructure **56**. The mobile interface **24** may be a software interface that records statistical information related to inbound and outbound data. The mobile interface **24** may also be responsible for error detection and correction, and establishing and managing the mobile data sessions with the remote devices **52**. The number of mobile interfaces **24** provided in the remote network controller **20** depends on the number of different types of radio infrastructures **56** employed by the user. Each type of radio infrastructure **56** may have its own associated mobile interface **24**.

As shown in FIG. **5**, the mobile interface **24** may include an event handler and multithreading dispatcher **60**, a process initialization module **62**, a mobile session manager **64**, an inbound data event handler **66**, an outbound data event handler **68**, a process termination module **70** and a host data controller interface module **72**. The event handler and multithreading dispatcher **60** may contain high-level logic and be used to control the overall execution flow of the mobile interface **24**. The process initialization module **62** may be utilized to acquire resources and establish the operation environment for the mobile interface **24** process. The process initialization module **62** may also be provided to initialize the host data controller **22**.

According to the present invention, the mobile session manager **64** may be provided to control the communications environment between the mobile data controller **54** and the host data controller **22**. The inbound data event handler **66** responds to signals from the host data controller **22** indicating that inbound data is available and preprocess session control information. The outbound data event handler **68** is provided to respond to signals from the interprocess communication manager **28** indicating that outbound data is available or that a session control function is required. The process termination module **70** functions to release previously-acquired resources and terminate the mobile interface **24** process efficiently. The host data controller interface module **72** handles low-level interaction with the associated host data controller(s) **22**.

The process flow of the event handler and multithreading dispatcher **60** will now be described with reference to FIG. **6**. At step **600**, the process begins when the remote network controller **20** is powered up and initialized. At step **602**, the process initialization module **62** is invoked (described below with reference to FIG. **7**). At step **604**, the event handler and multithreading dispatcher **60** waits for an event (e.g., receipt of inbound data) to occur. While the event handler and multithreading dispatcher **60** waits for an event to occur, mobile interface **24** may be placed in a "sleep" mode to conserve processor resources. At step **606**, once an event occurs, the event handler and multithreading dispatcher **60** determines if it is a recognized event. If the event handler and multithreading dispatcher **60** determines it is not a recognized event at step **606**, processing returns to step **604**. If, however, the event handler and multithreading dispatcher **60** determines that the event is a recognized event at step **606**, then processing continues at step **608**, where the event handler and multithreading dispatcher **60** determines if the data was received from the host data controller **22**.

At step **608**, if the event handler and multithreading dispatcher **60** determines the data was received from the host data controller **22**, the event handler and multithreading dispatcher **60** invokes the inbound data event handler **66**, at step **614** (described below with reference to FIG. **9**) and processing continues at step **604**. If at step **608** the event handler and multithreading dispatcher **60** determines that the data was not received from the host data controller **22**, then the event handler and multithreading dispatcher **60** determines whether the data was received from the service interface **30** at step **610**.

If the event handler and multithreading dispatcher **60** at step **610** determines that the data was received from the service interface **30**, then at step **616** the outbound data event

handler **68** is invoked (described below with reference to FIG. **10**) and processing returns to step **604**. If the event handler and multithreading dispatcher **60** at step **610** determines that the data was not received from the service interface **30**, then at step **612** the event handler and multithreading dispatcher **60** determines if there is a process termination request.

If, at step **612**, the event handler and multithreading dispatcher **60** determines there is a process termination request, then at step **618**, the process termination module **70** is invoked (described below with reference to FIG. **11**). If, at step **612**, the event handler and multithreading dispatcher **60** determines that there is not process termination request, then processing continues at step **604** to wait for another event.

Referring now to FIG. **7**, there is illustrated an exemplary flow chart for indicating the process flow of the process initialization module **62** of FIG. **5**. At step **620**, the interprocess communications interface is setup. At step **622**, the operating environment parameters are parsed and processed. This includes the host data controller **22** parameters referenced in steps **626**, **632** and **634** below. At step **624**, memory is allocated for the session and other tables contained within the mobile interface **24**, which are used to control data flow and other operations. At step **626**, the host data controller **22** parameters are accessed. At step **628**, a path to the host data controller **22** port is opened. At step **630**, the host data controller **22** then is prevented from monitoring for an event from the remote device(s) **52**. Step **630** prevents erroneous transmissions that may arise if the host data controller **22** attempts to monitor a remote device **52** before the initialization process is complete. At step **632**, the host data controller **22** communication parameters are set. At step **634**, the communication parameters are downloaded to the host data controller **22**. After the initialization processes of steps **632** and **634** are completed, the host data controller **22** at step **636** is enabled to monitor the remote device(s) **52**. At step **638**, the entire initialization procedure is complete and processing returns to step **604** in FIG. **6**.

Referring now to FIG. **8**, there is illustrated an exemplary flow chart describing the logic flow of the mobile session manager **64** of FIG. **5**. At step **640**, the mobile session manager **64** handler is entered from the event handler and multithreading dispatcher **24** when remote data is detected. At step **642**, the remote identifier of the remote device **52** is looked up in a session table. At step **644**, the mobile session manager **64** determines if the remote identifier was found in the session table. If the mobile session manager **64** determines that the remote identifier was found, the address is returned from the session table at step **646**.

If the mobile session manager **64** does not find the remote identifier at step **644**, then at step **648** the mobile session manager **64** attempts to authenticate the remote identifier. At step **650**, the mobile session manager determines if the authentication is successful. If at step **650** the authentication is successful, then at step **656** the host data controller **22** is instructed to connect to the remote device **52** based on the remote identifier. After the host data controller **22** is connected to the remote device **52**, the appropriate service interface **30** is invoked at step **658**. At step **660**, processing is complete. If at step **650**, the authentication was not successful, the remote data is ignored at step **652**, and a null session table entry address is returned by the mobile session manager **64**.

Referring now to FIG. **9**, there is illustrated an exemplary flow chart of the processing steps of the inbound data event handler **66** of FIG. **5**. At step **662**, the inbound data event handler is invoked (from step **614** in FIG. **6**). At step **664**, the remote identifier of the remote device **52** is checked against the session table. At step **666**, it is determined whether the inbound data event handler **66** found the remote identifier in the session table. If at step **666**, the remote identifier is not found in the session table, the data is ignored and processing continues at step **604** in FIG. **6**. If the remote identifier is found in the session table at step **666**, the data is sent to the service interface **30** at step **670**. Processing then continues at step **604** in FIG. **6**.

Referring now to FIG. **10**, there is illustrated an exemplary flow chart of the processing steps of the outbound data event handler **68** of FIG. **5**. At step **672**, the outbound data event handler is invoked (from step **616**, FIG. **6**). At step **674**, the session table is checked for the outbound data remote identifier. At step **676**, it is determined if the outbound data event handler **68** found the remote identifier in the session table. If at step **676**, the remote identifier is not found in the session table, an error is logged and the data message is ignored. Processing then continues at step **604** in FIG. **6**. If the remote identifier is found in the session table at step **676**, the data is sent to the remote device **52** as a single packet at step **680**. Processing then continues at step **604** in FIG. **6**.

Referring now to FIG. **11**, there is illustrated an exemplary flow chart of the processing steps of the process termination module **70** of FIG. **5**. At step **682**, the process termination module **70** is invoked (from step **618** in FIG. **6**). At step **684**, the process termination module **70** determines if there are any active remote sessions. If, at step **684**, it is determined by the process termination module **70** that there are no active sessions, then at step **686** all files are closed and the mobile interface **24** terminates. If, however, it is determined by the process termination module **70** that there are active sessions, then at step **688** all of the active sessions are issued a disconnect request. At step **690**, the process termination module waits for all active sessions to terminate. Once all active sessions have terminated at step **690**, then all files are closed and the mobile interface **24** terminates at step **686**.

Referring now to FIG. **12**, there is illustrated an exemplary flow chart of the processes associated with the host data controller interface module **72** of FIG. **5**. The host data controller interface module **72** consists of a number of discrete functions (e.g., Initialize, Command, Send Data, and Receive Data) which are called when needed by the mobile interface **24** and share common information about the host data controller **22**. The host data controller interface module **72** may access the host data controller **22** via a serial communications port which is assigned to the mobile interface **24** and remains fixed when the remote network controller **20** is in operation.

A host data controller **22** initialize routine begins at step **692**. The initialization routine may be initiated in accordance with step **602** (see FIG. **6**) and steps **632** and **634** (see FIG. **7**). At step **694**, the serial communications port is accessed and setup. Thereafter, at step **696**, the port handle and status is saved to be used by other processes within the host data controller interface module **72**.

A host data controller **22** command routine begins at step **698**. The command routine may be initiated upon the occurrence of a recognized event (see, e.g., step **604** in FIG. **6**) so that the appropriate control or operation commands may be sent to the host data controller **22**. At step **700**, the host data controller **22** is placed into a command mode. At

step **702**, a command (e.g., disconnect or receive) is issued to the host data controller **22** based on the event that is recognized. At step **704**, the host data controller interface module **72** awaits a confirmation of acceptance of the command from the host data controller **22**. At step **706**, the result of the command is returned to the host data controller interface module **72**.

A host data controller **22** send data routine begins at step **708** and may be initiated from step **680** in FIG. **10**. The send data routine is initialized so that data may be sent to the appropriate remote device **52**. First, the physical identification of the remote device **52** is determined at step **710**. Thereafter, the data to be sent to the remote device **52** is placed into a packet at step **712**, and sent to the host data controller **22** at step **714**.

At step **716**, a host data controller **22** receive data routine is initiated in accordance with step **670** in FIG. **9**. The receive data routine is initiated so that data from the remote device **52** may be received by the remote network controller **20**. At step **718**, data is accumulated within the host data controller **22** receive data routine (see, FIG. **12**, step **716**) until a full packet of information is received. Thereafter, at step **720**, the packet is identified as either session oriented or monitor oriented data. The identified data packet is then returned, at step **722**, to the mobile interface **24** and sent to the wired communication network **10** via the remote network controller **20**.

Referring now to FIG. **13**, in accordance with an aspect of the present invention, there is illustrated a block diagram of the basic components of the host data controller **22** (see, e.g., FIG. **2**) of the present invention. The host controller **22** may be physically connected external to the remote network controller **20** via the mobile interface **24**. The host data controller **22** is specifically designed to convert the radio infrastructure **56** protocol to the internal protocol of the remote network controller **20**. Typically, one host data controller **22** may be connected to each mobile interface **24**; however, one or more host data controllers **22** may be connected for redundancy and greater reliability.

As shown in FIG. **13**, the host data controller **22** may comprise an RF communications interface module **80**, a remote network controller communications interface module **78**, and a configuration and monitoring module **82**. The host data controller **22** may comprise any combination of hardware and software to perform the functions described herein. For example, the host data controller **22** may comprise a commercially available processor or multi-processor with overlying application software. The software running in the host data controller **22** may be written in Z80 or other appropriate high-level language (e.g., Pascal). The host data controller **22** may also contain a plurality of serial ports for communicating with other devices.

The remote network controller communications interface module **78** is connected to the mobile interface **24** of the remote network controller **20** and is responsible for sending and receiving data to and from the remote network controller **20**. A subsystem port **76** (e.g., an RS-232 adapter) may be used to connect the remote network controller communications interface module **78** to the mobile interface **24** of the remote network controller **20**. If the host data controller **20** is connected to more than one remote network controller, then additional subsystem port connection(s) may also be provided to connect to the interface module **78** to the additional remote network controllers. The remote network controller communications interface module **78** sends health and status information regarding the host data controller **22** to the mobile interface **24**. This information informs the remote network controller **20** that the host data controller **22** is operational and accepting data.

The configuration and monitoring module **82** is specific to the type of radio infrastructure **56** employed. Software parameters, such as the number of subsystem ports, how often to send health and status requests, and a list of mobile data controllers **54** to which the host data controller **22** can communicate, may be set and stored in the configuration and monitoring module **82**. The configuration and monitoring module **82** can also accumulate statistics which are passed to the mobile interface **24**.

In order to diagnose potential system errors in the host data controller **22**, the remote network controller **20** may test and analyze the host data controller **22** over a diagnostic port (not shown) to determine a cause of the system failure or error. The diagnostic port may be used not only to determine if the host data controller **22** is operational, but also to configure software parameters particular to the type of radio infrastructure **56**. These parameters can be changed to communicate with a different radio infrastructure **56** type as necessary.

The RF communications interface module **80** is responsible for sending and receiving the radio-frequency transmissions. The RF communications interface module **80** is specific to the radio infrastructure **56** in use and is connected to the radio infrastructure **56** by a communication line **57**. Again, because the host data controller **22** is designed to integrate with an existing radio infrastructure **56**, each host data controller **22** is software configured to work with many different types of radio infrastructure **56** protocols for flexibility. The host data controller **22** may be designed to be plugged into the remote network controller **20**, connecting to the mobile interface **24**, and can simply be exchanged with a different host data controller **22**, or reprogrammed depending on the radio infrastructure **56** employed. Host data controllers **22** may be configured so as to be compatible with, for example, conventional point-to-point radio systems, conventional repeater-based radio systems, LTR Trunking, Motorola Trunking, Ericsson (EDACS) Trunking—Voice Path, EDACS RDI Trunking—Data Path, and EDACS IMC Voice Path radio infrastructures.

Referring to FIG. **14**, there is illustrated a block diagram of the components comprising the service interface **30** (see FIG. **2**) of the present invention. The service interface **30** is responsible for communicating to and from the wired communication network **10**. The service interface **30** is concerned only with the software level protocols of the wired communication network **10**. The hardware interface to the wired communication network **10** is accomplished by a known network control card, such as an Ethernet controller or a Token-Ring controller.

The number of service interface **30** connections to the wired communication network **10** is dictated by the type of wired communication network **10**. If the wired communication network **10** uses asynchronous data transfer, there will be one service interface **30** for every entry point, e.g., serial port, into the wired communication network **10**. In a local area network (LAN) environment, each service interface **30** may handle a variety of different network addresses. A different service interface **30** may be used for each type of wired communication network **10**.

As shown in FIG. **14**, the service interface **30** may include an event handler and multithreading dispatcher **90**, a process initialization module **92**, an inbound data event handler **94**, an outbound data event handler **96**, a process termination

module **98** and a wired network interface module **100**. The event handler and multithreading dispatcher **90** may contain high-level logic and be used to control the overall execution flow of the service interface **30**. The process initialization module **92** acquires resources and establishes the operation environment of the service interface **30** process. The inbound data event handler **94** responds to signals from the interprocess communication manager **28** that inbound data is available and preprocess session control information. The inbound data event handler **94** may also handle asynchronous timer events. The outbound data event handler **96** is provided to respond to signals from wired communication network interface module **100** that outbound data is available or that a timer event has occurred. The process termination module **98** functions to release previously-acquired resources and terminate the service interface **30** process gracefully. The wired communication network interface module **100** handles low-level interaction with the associated wired communication network transport mechanism, i.e., communication protocol, being used.

An exemplary process flow of the event handler and multithreading dispatcher **90** (see FIG. **14**) of the present invention will now be described with reference to FIG. **15**. At step **800**, the process begins when the service interface **30** is powered up and initialized. At step **802**, the process initialization module **92** is invoked (described below with reference to FIG. **16**). At step **804**, the event handler and multithreading dispatcher **90** waits for an event to occur in response, e.g., to network or remote device activity. While the event handler and multithreading dispatcher **90** waits for an event to occur, the service interface **30** may be placed in a "sleep" mode to conserve processing power. At step **806**, once an event occurs, the event handler and multithreading dispatcher **90** determines if it is a recognized event. Recognized events may include Initialize, Send Data, Receive Data and/or Terminate. If the event handler and multithreading dispatcher **60** determines it is not a recognized event at step **806**, then processing returns to step **804**. If the event handler and multithreading dispatcher **90** recognizes the event at step **806**, then processing continues at step **808**, where the event handler and multithreading dispatcher **90** determines if the data was received from the host communication network **10**.

At step **808**, if the event handler and multithreading dispatcher **90** determines the data was received from the host wired communication network **10**, the event handler and multithreading dispatcher **90** invokes the inbound data event handler **94**, at step **814** (described below with reference to FIG. **17**) and, thereafter, processing continues at step **804**. If at step **808** the event handler and multithreading dispatcher **90** determines that the data was not received from the host wired communication network **10**, the event handler and multithreading dispatcher **90** then determines if the data was received from the mobile interface **24** at step **810**.

If the event handler and multithreading dispatcher **90** determines at step **810** that the data was received from the mobile interface **24**, then at step **816** the outbound data event handler **96** is invoked (described below with reference to FIG. **18**) and, thereafter, processing continues at step **804**. If the event handler and multithreading dispatcher **90** at step **810** determines that the data was not received from the mobile interface **24**, then at step **812** the event handler and multithreading dispatcher **90** determines if there is a process termination request.,

If, at step **812**, the event handler and multithreading dispatcher **90** determines there is a process termination request, then at step **818** the process termination module **98** is invoked (described below with reference to FIG. **19**). However, if at step **812** the event handler and multithreading dispatcher **90** determines that there is not process termination request, then processing returns to step **804** to wait for another event.

Referring now to FIG. **16**, there is illustrated an exemplary flow chart describing the process flow of the process initialization module **92** (see, e.g., FIG. **14**) of the present invention. At step **820**, the interprocess communications interface is setup when the service interface **30** is started or powered up. At step **822**, the operating environment parameters are parsed and processed (i.e., the parameters of the operating environment are processed individually). At step **824**, any resources required (e.g., memory) are acquired. Thereafter, at step **826**, the wired communication network interface module **100** is invoked (see FIGS. **20–24** discussed below). As discussed below, the wired communication network interface module **100** may include several procedures associated with initializing the connectivity with the wired communication network **10**, reading data from the wired communication network **10**, writing data to the wired communication network **10**, and terminating connectivity with the wired communication network **10**. In accordance with an aspect of the present invention, a unique set of procedures may be provided by the wired communication network interface module **100** for each type of wired communication network **10**. For example, a unique set of procedures may be provided for networks utilizing transparent asynchronous communications, TCP/IP stream sockets, Vehicle Location Reporting Facilities, Bidirectional Messaging Facilities, or Credit Card Verification Facilities.

After the wired communication network interface module **100** is invoked, the results of the previous operations performed at step **826** are sent at step **828** to the mobile interface **24**. At step **830**, it is determined by the process initialization module **92** if the wired communication network interface module **100** was successfully invoked at step **826**. If it is determined at step **830** that the wired communication network interface module **100** was successfully invoked, then the initialization is complete at step **832**, and processing returns to step **804** in FIG. **15**. If, however, it is determined at step **830** that the wired communication network interface module was not successfully invoked, then the service interface **30** is terminated at step **834**.

Referring now to FIG. **17**, there is illustrated an exemplary flow chart of the processing steps for the inbound data event handler **94** (see, e.g., FIG. **14**) of the present invention. At step **836**, the inbound data event handler is invoked (from step **814** in FIG. **15**). At step **838**, the data portion of the message sent by the wired communication network **10** is extracted. At step **840**, the service interface **30** requests a packet of data from the mobile interface **24**. At step **842**, after the packet is accepted by the service interface **30**, data is sent to the appropriate destination via the wired communication network **10**. The inbound data event handler **94** then waits for a disconnect request at step **844**. If the inbound data event handler **94** receives a disconnect request at step **844**, then a disconnect command is sent to the mobile interface **24** at step **846**. Processing then continues at step **804** in FIG. **15**. If, however, the inbound data event handler **94** does not receive a disconnect request at step **844**, then the request received is ignored at step **848** and, thereafter, processing then continues at step **804** in FIG. **15**.

Referring now to FIG. **18**, there is illustrated an exemplary flow chart of the processing steps for the outbound data event handler **96** (see FIG. **14**) of the present invention. At step **850**, the outbound data event handler is invoked (from

step **816** in FIG. **15**). At step **852**, the outbound data event handler **96** determines if there is a request (e.g., a disconnect request from the wired communication network **10** or the remote device **52**). If there is a request, then processing continues at step **856**. However, if there is presently not a request, then at step **854** the outbound data from the network **10** is sent to remote device **52** via the mobile interface **24**. At step **865**, the outbound data event handler **96** then determines if a disconnect request has been received. If the outbound data event handler **96** receives a disconnect request at step **856**, then a disconnect command is sent to the mobile interface **24** at step **860** by the interprocess communication manager **28** (see, e.g., FIG. **2**). Processing then continues at step **804** in FIG. **15**. If, however, the outbound data event handler **96** does not receive a disconnect request at step **856**, then the request received is ignored at step **862** and processing then continues at step **804** in FIG. **15**.

Referring now to FIG. **19**, there is illustrated an exemplary flow chart of the processing steps for the process termination module **98** (see FIG. **14**) of the present invention. At step **864**, the process termination module **98** is invoked (from step **818** in FIG. **15**). At step **866**, the wired communication network interface module **100** connection is closed. Thereafter, at step **868**, the processes associated with the service interface **30** are terminated.

Referring now to FIGS. **20–24**, there are illustrated exemplary flow charts of the various processes that may be performed by the wired communication network interface module **100** of the present invention. The wired communication network interface module **100** may consist of a number of discrete functions which provide the service interface **30** with a uniform means of communicating with various host computer networks, irrespective of the communication protocols of the wired communication network **10**. All protocol and other feature-specific communications translation and handling is performed at the wired communication network interface module **100**. The wired communication network interface module **100** may be designed for networks utilizing different implementations, such as transparent asynchronous communication, Hayes compatible communication, TCP/IP stream socket, Bidirectional Messaging Facilities, File Transfer Facilities, SNA Protocol Enveloping, Vehicle Location Reporting Facilities, Credit Card Verification Facilities, and Harris DNP 3.0 Frame Relay. As noted above, a unique set of procedures may be provided by the wired communication network interface module **100** for each type of wired communication network **10**. Examples of several of these sets of procedures are provided below.

Referring now to FIG. **20**, there is illustrated an exemplary flow chart of the set of procedures associated with the wired communication network interface module **100** that are designed for transparent asynchronous communication networks. At step **900**, an initialization process begins in accordance, for example, with step **802** of FIG. **15**. At step **902**, the serial port of the wired communication network **10** that is to be used is determined, and the identified port is opened or accessed at step **904**. At step **906**, the speed (bps), the parity (odd or even), and the data bits for communication with the network **10** are established along with other appropriate parameters.

At step **908** a data read operation begins. The data read routine may be invoked by the outbound data event handler **96** at step **850** (see FIG. **18**). Initially, at step **910**, the wired communication network interface module **100** determines if there is data to be read from the serial port. If at step **910** the wired communication network interface module **100** determines there is data to be read, then at step **916** the data is added to an accumulated data buffer within the remote network controller **20**. At step **918**, if the wired communication network interface module **100** determines that the data buffer is full, then at step **914** the data accumulated in the buffer is returned to the calling module. If, however, at step **910** the wired communication network interface module **100** determines there is no data to be read from the serial port attached to the network **10**, then at step **912** it is determined if the inter-character time (e.g., a predetermined character receipt delay time) has been exceeded. If at step **912** the inter-character time has been exceeded, then at step **914** the accumulated data buffer is returned to the calling module to be further processed. Otherwise, if the inter-character time has not been exceeded, then processing continues at step **910** so that the wired communication network interface module **100** may again determine if there is data to be read from the serial port.

At step **920**, a write data routine is started. The write data routine may be initiated by the inbound data event handler **94** at step **836** in FIG. **17**. At step **922**, the data is sent directly to the serial port of the wired communication network **10**. The write data routine is thereafter completed.

At step **924**, a terminate routine is initiated. The terminate routine may be initiated in accordance with a terminate request at step **818** in FIG. **15**. In response to initiation of the terminate routine, the serial port of the network **10** is closed at step **926**. Thereafter, at step **928**, the serial port resource is released so it may be used by another process. Finally, at step **930**, any data buffers in use are also released.

Referring now to FIG. **21**, there is illustrated exemplary flow charts of the set of procedures associated with the wired communication network interface module **100** for networks utilizing TCP/IP stream socket connectivity. At step **932**, an initialization process begins in accordance, for example, with step **802** of FIG. **15**. At step **934**, a host network and serial port to be used are determined. At step **936**, an appropriate socket is created. At step **938**, the socket server is accessed for data transport.

At step **940** a data read operation begins. The data read routine may be invoked the outbound data event handler **96** at step **850** (see FIG. **18**). Initially, at step **942**, the wired communication network interface module **100** determines if there is data to be read from the socket. If at step **942** the wired communication network interface module **100** determines there is data to be read, then at step **944** the data buffer is returned to the remote network controller **20** for further processing.

At step **946**, a write data routine is started. The write data routine may be initiated by the inbound data event handler **94** at step **836** in FIG. **17**. At step **948**, the data is sent by the wired network interface module **100** directly to the socket at the wired communication network **10**. The write data routine is thereafter completed.

At step **950**, a terminate routine is initiated. The terminate routine may be initiated in accordance with a terminate request at step **818** in FIG. **15**. Initially, the socket is closed at step **952**. Thereafter, at step **954**, the socket resource is released so it may be used by another process. Finally, at step **956**, any data buffers in use are also released.

Referring now to FIG. **22**, there is illustrated exemplary flow charts of the set of procedures associated with the wired communication network interface module **100** for use with networks utilizing Vehicle Location Reporting Facilities. At step **958**, an initialization process begins in accordance, for example, with step **802** of FIG. **15**.

At step **960** the wired communication network interface module **100** determines a position recording file to be used to record data. The position recording file may be stored within the wired communication network **10**. At step **962**, the position recording file is accessed from the network **10**. Thereafter, at step **964**, the recording interval is placed into a read buffer that may be provided to the remote device **52** via the mobile data controller **54**.

At step **966** a data read operation begins. The data read routine may be invoked by the outbound data event handler **96** at step **850** (see FIG. **18**). Initially, at step **968**, the wired communication network interface module **100** determines if there is data in the read buffer. If at step **968** the wired communication network interface module **100** determines there is data in the read buffer, then at step **970** the contents of the read buffer is returned to the calling module.

At step **972**, a write data operation is started. The write data routine may be initiated by the inbound data event handler **94** at step **836** in FIG. **17**. Initially, at step **974**, the wired communication network interface module **100** determines if a full Global Positioning Satellite (GPS) message has been accumulated. If at step **974**, the wired communication network interface module **100** determines that a full GPS message has not been accumulated, then no action is taken at step **980**. If at step **974**, the wired communication network interface module **100** determines that a full GPS message has been accumulated, then the message is converted at step **976** to a standard form usable by the wired communications network **10**. At step **978**, the position recording file at the host is appended with the GPS message.

At step **982**, a terminate routine is initiated. The terminate routine may be initiated in accordance with a terminate request at step **818** in FIG. **15**. The terminate routine may comprise closing the position recording file at step **984**.

Referring now to FIGS. **23**A and **23**B, there is illustrated exemplary flow charts of the set of procedures associated with the wired communication network interface module **100** that are designed for networks utilizing Bidirectional Messaging Facilities or Store and Forward Messaging Facilities. Referring to FIG. **23**A, at step **986**, an initialization process begins. The initialization process may be started in accordance, for example, with step **802** of FIG. **15**. At step **988**, a message queue for the remote device **52** is accessed. Thereafter, at step **990**, if no queue exists for the remote device **52**, a message queue is created at the remote network controller **20**.

At step **992** a data read operation begins. The data read routine may be invoked by the outbound data event handler **96** at step **850** (see FIG. **18**). Initially, at step **994**, the wired communication network interface module **100** determines if a message is in the process of being sent. If at step **994** the wired communication network interface module **100** determines that a message is being sent, then at step **998**, the current message segment is sent by the remote device **52** to the wired communication network **10**. If at step **994** the wired communication network interface module **100** determines that no message is being sent, then at step **996**, the wired communication network interface module **100** determines if there is a message queued. If at step **996** the wired communication network interface module **100** determines that no messages are queued then no action is taken. However, if at step **996** the wired communication network interface module **100** determines that there is a message queued for the remote device **52**, then the current message queued is sent at step **998**. After the last segment of the message is sent, the wired communication network interface module **100** may indicate that delivery of the message is pending to the remote device **52** at step **1000**.

At step **1002**, a write data routine is initiated. The write data routine may be initiated by the inbound data event handler **94** at step **836** in FIG. **17**. Initially, at step **1004**, the wired communication network interface module **100** determines if a new message is present. If at step **1004** the wired communication network interface module **100** determines that a new message is present, then at step **1010** the wired communication network interface module **100** starts a new queue entry. Thereafter, processing continues at step **1006**, where the message segment is recorded. At step **1008**, the wired communication network interface module **100** determines if this is the last segment. If at step **1008** the wired communication network interface module **100** determines that it is the last segment, then at step **1012**, the queue entry is closed and "Message Received" message may be placed into the read buffer at step **1014** to be sent to the remote device **52**. If at step **1008**, the wired communication network interface module **100** determines that it is not the last segment, then no action is taken.

Referring to FIG. **23**B, at step **1016**, a terminate routine is started. The terminate routine may be initiated in accordance with a terminate request at step **818** in FIG. **15**. At step **1018**, the wired communication network interface module **100** determines if the terminate request has come in the middle of a message. If at step **1018**, the wired communication network interface module **100** determines that the request came in the middle of a message, then the message is purged at step **1022**. Processing then continues at step **1020**, where the wired communication network interface module **100** closes the message queue.

Referring now to FIG. **24**, there is illustrated flow charts of the set of procedures associated with the wired communication network interface module **100** designed for use with networks utilizing Credit Card Point-of-Sale Facilities. At step **1024**, an initialization process begins. The initialization process may be started in accordance, for example, with step **802** of FIG. **15**. In accordance with the invention, no action is required for the initialization procedure.

At step **1026** a data read operation begins. The data read routine may be invoked the outbound data event handler **96** at step **850** (see FIG. **18**). Initially, at step **1028**, the wired communication network interface module **100** determines if there is a response from a server attached to the wired communication network **10**. If at step. **1028** the wired communication network interface module **100** determines there is a response from the server, then at step **1030** the response is read, and the response buffer is returned to the remote device **52** at step **1032**. If at step **1028** there is no response from the server, then no action is taken.

At step **1034**, a write data operation is started. The write data routine may be initiated by the inbound data event handler **94** at step **836** in FIG. **17**. At step **1036**, the wired communication network interface module **100** first determines if a full request by the remote device **52** has been accumulated. If at step **1036** the wired communication network interface module **100** determines that a full request has not been accumulated, then the remote device **52** continues to accumulate a request at step **1042**. If at step **1036** a full request has been accumulated, then at step **1038**, the request is formatted for the server on the wired communications network **10**. Thereafter, the request is placed into the server file at step **1040**.

At step **1044**, a terminate routine is illustrated. The terminate routine may be initiated in accordance with a

terminate request at step **818** in FIG. **15**. According to the present invention, no action is necessary for the terminate routine.

Referring now to FIG. **25**, there is illustrated a block diagram of the various components of the mobile data controller **54**, according to another aspect of the present invention. The mobile data controller **54** may be specifically designed to match the asynchronous data transferred to and from the remote device **52** to the radio infrastructure **56** protocol. Typically, there is one type of mobile data controller **54** that is associated with a host data controller **22** which is connected to the mobile interface **24** of the remote network controller **20**. In addition, the mobile data controller **54** may have a unique identifier associated with it for routing purposes.

In accordance with the present invention, the mobile data controller **54** may be implemented by any combination of hardware and software. For example, the mobile data controller **54** may comprise a commercially available processor with overlying software and random access memory. The software running in the mobile data controller **54** may be written in Z80 or other appropriate processor-based (i.e., native) assembly language and configured to the specific radio infrastructure **56**. The software may specify the various voltage levels and logic signals necessary to communicate via the RF communications infrastructure **56**. As noted above, the mobile data controller **54** may translate and pass any protocols associated with the wired communications network **10** to and from the remote device **52** to make it appear to the wired communication network **10** that the remote device **52** is locally-attached.

The mobile data controller **54** is configurable over the radio infrastructure **56**. configuration information may be input by an operator at the remote network controller **20** through the console interface **34** (see FIG. **2**) and passed over the radio infrastructure **56** to the mobile data controller **54**. This allows parameters such as packet size to be changed at the host wired communications network **10** without the necessity of altering the mobile data controller **52** in the field.

As shown in FIG. **25**, the mobile data controller **54** may comprise an RF communications interface module **106**, a remote device communications interface module **102**, and a configuration and monitoring module **104**. The mobile data controller **54** may be connected to the remote device **52** via a communication port **108** for sending and receiving data. The remote device communications interface module **102** is connected to the remote device **52** via the communication port **108** and is responsible for sending data to, and receiving data from, the remote device **52**. The communication port **108** may comprise, for example, an RS-232 adapter.

The configuration and monitoring module **104** is specific to the type of radio infrastructure **56** employed. Software parameters, such as the number of subsystem ports, how often to send health and status requests, and a list of host data controllers **22** to which the mobile data controller **54** can communicate, may be set and stored in the configuration and monitoring module **104**. The configuration and monitoring module **104** can also accumulate statistics which are passed to the host data controller **22**.

In order to diagnose potential system errors in the mobile data controller **54**, an operator may be provided with the ability to field test and analyze the mobile data controller via an external diagnostic port **112** to determine a cause of the system error or failure. The diagnostic port **112** may be used not only to determine if the mobile data controller **54** is operational, but also can be used to configure software parameters to determine the type of the radio infrastructure **56**. These parameters can be changed to communicate with a different type of radio infrastructure **56** as necessary.

The RF communications interface module **106** is responsible for sending and receiving the data via radio-frequency (RF) transmission. The RF communications interface module **106** is specific to the radio infrastructure **56** used, and is connected to the radio infrastructure **56** through a communication line **110**. Because the mobile data controller **54** is designed to integrate with an existing radio infrastructure **56**, each mobile data controller **54** may be software configured, for purposes of flexibility, to work with many types of radio infrastructure **56** protocols. The RF communications interface module **106** may also send health and status information regarding the mobile data controller **54** to the host data controller **22**. This information may inform the remote network controller **20** that the mobile data controller **54** is operational and the remote device **52** is accepting data.

According to the present invention, the RF communication interface module **106** may include a commercially available modem (not shown). The modem may be selected depending on the data rate(s) of the communication line **100** and the radio infrastructure **56**. More than one modem may be provided if multiple data rates are required. Optionally, the modem can be implemented using a Digital Signal Processing (DSP) chip and associated software. The DSP chip can be a commercially available programmable signal processing chip. In such a case, the DSP implementation will allow a single modem to be changed (e.g., by uploading new parameters to the DSP software) in order to communicate with a plurality of different types of radio infrastructures **56** having distinct protocols and data rates.

Similar to the host data controllers **22**, the mobile data controllers **54** may be compatible with, for example, conventional point-to-point radio systems, conventional repeater-based radio systems, LTR Trunking, Motorola Trunking, Ericsson (EDACS) Trunking-Voice Path, EDACS RDI Trunking-Data Path, and EDACS IMC Voice Path based radio infrastructures **56**.

Referring again to FIG. **2**, a brief description of the interprocess communications manager **28** will be provided. According to the present invention, the interprocess communications manager **28** is responsible for routing all communication between the various modules and interfaces within the remote network controller **20**. The interprocess communications manager **28** creates a logical route from the remote device **52** to the service interface **30** of the remote network controller. The interprocess communications manager **28** passes routing information which determines from which radio infrastructure **56** and remote device **52** the inbound data has come from, and to which radio infrastructure **56** and remote device **52** the outbound data will be sent.

The interprocess communications manager **28** may also pass information generated by the remote network controller **20**, which is independent of the data and routing information. This information may include internal parameters and error detection codes. The interprocess communications manager **28** also interfaces with the control process module **26**. The control process **26** may act as the "central hub" of the remote network controller **20**. The control process **26** provides resource management, process management, session management, configuration management and system statistics management within the remote network controller **20**.

As further shown in FIG. **2**, the remote network controller **20** also includes a console interface **34**. The console inter-

face **34** may be adapted to allow a network operator to configure and control the wireless Network Interfaces described above, the mobile user characteristics and the configuration information of the wired communications network **10**. The console interface **34** may be a stand-alone platform having a commercially available processor (e.g., an Intel or Motorola based processor) and an Ethernet controller card for communicating, for example, with another remote network controller **20**.

Referring now to FIG. **26**, there is illustrated a remote gateway **120**, in accordance with another aspect of the present invention. As shown in FIG. **26**, the remote gateway **120** is comprised of a transparent communications module **122**, a field service interface module **128**, a configuration and health module **124** and a RF communications module **126**. The remote gateway **120** is functionally similar to the mobile data controller **54**. However, the remote gateway **120** is a specific type of mobile data controller that may be used to attach to a remote telemetry unit for monitoring, for example, electrical power distribution.

The transparent communications module **122** is responsible for communicating with a terminal device, typically a Remote Telemetry Unit (RTU) located in the field, and accepts data from the RF communications module **126**. As shown in FIG. **26**, the transparent communications module **122** may be connected to a RTU **133** via a communication line **130**. The transparent communications module **122** does not recognize any protocol, but handles hardware flow control and buffering and packetizing. Data communication between the transparent communications module **122** and the RTU **133** may be carried through asynchronous serial transfer.

The RF communications module **126** is configured to communicate with the remote network controller **20** using whatever protocol is required for data transport over the radio infrastructure **56**. The RF communications interface module **126** interfaces with the radio infrastructure **56** in a similar manner as previously described above with regard to the RF communications interface module **106**. The RF communications interface module **126** accepts data from the transparent communications module **122** and delivers it to the radio infrastructure **56** for transmission to the remote network controller. The RF communications interface module **126** detects collisions with inbound RF data and restarts outbound transmissions. The RF communications interface module **126** performs error/retry functions and notifies the transparent communications module **122** of successes or failures.

The field service interface module **128** allows a technician to field test the remote gateway **120** and troubleshoot the remote gateway should a system error or problem arise. An external diagnostic port **112** connected to the field service interface module **128** may be provided for this purpose. The field service interface module **128** may interact with the configuration and health module **124** to query, set, and reset local configuration of the remote gateway **120**.

The configuration and health module **124** may accept configuration information from the remote network controller **20** via the radio infrastructure **56** and adjust the operating parameters of the remote gateway **120** accordingly. The configuration and health module **124** may also monitor and determine if the RF communications module **126** has successfully transmitted a packet of information to the host data controller **22** by analyzing the data stream. If a packet of information has not been successfully transmitted, the configuration and health module **124** may direct the RF communications module **126** to resend the packet of information to the host data controller **22**.

Referring now to FIGS. **27** and **28**, there is illustrated a block diagram of an integrated remote network controller **140** according to another aspect of the present invention. The components of the remote network controller **140** that are similar to that discussed above with respect to FIG. **2** are designated with the same reference numeral and also with a prime ("'") added thereto.

As shown in FIG. **27**, the remote network controller **140** according to another aspect of the present invention may include one or more service interfaces **30'**, an interprocess communications manager **28'**, a control process **26'**, one or more mobile interfaces **24'**, and a subsystem synchronization processor **150** which is used to link one or more remote network controllers **140** together (see FIG. **28**). As further shown in FIG. **27**, one or more host data controllers **22'** are connected to the mobile interfaces **24'** and provided externally to the remote network controller **140**. The number of host data controllers **22'** and mobile interfaces **24'** may be dependent on the number of radio infrastructures **56** present. In addition, the number of service interfaces **30'** may be dependent on the number and type of wired communications networks **10** present.

According to an aspect of the present invention, two remote network controllers **140** may be linked by a local network **152** (see FIG. **28**). This configuration provides a redundant system which insures greater reliability of communication between the remote device **52** and the wired communications network **10**. For example, should any particular component fail, such as a host controller **22'** or an interprocess communications manager **28'**, the remote device **52** can still communicate with the wired communication network **10** because of the redundancy of the components of the remote network controllers **140** provided.

There are two main implementations of this system according to the present invention. With the first implementation, only one of the remote network controllers **140** is operating at any given time. Should the operational remote network controller **140** fail, the other remote network controller **140** may immediately take its place. For example, if remote network controller "A" fails, then remote network controller "B" may be activated to take its place.

Under the second implementation, a distributed processing scheme is utilized and both of the remote network controllers **140** are operated at the same time. According to the distributed processing scheme, the processing load (e.g., event handling and data transfer) may be distributed among the operational remote network controllers **140**. Should a particular remote network controller **140** (e.g., controller "B") fail, the remaining operational remote network controller **140** (e.g., controller "A") will handle the entire processing load.

The above-mentioned distribution of the processing load is generally a function of the radio infrastructure **56**, and not the processing capacity of the remote network controllers **140**. This is because performance increases are mainly based on the number of available communications channels, rather than the raw processing capability of the remote network controllers **140** attached to the wired communications network **10**. For example, if the radio infrastructure **56** is a trunking radio network with five channels, it is possible for all five channels to be simultaneously allocated and used by the remote network controllers **140**. On the other hand, if there is only one channel available in the radio infrastructure **56**, then only one remote network controller **140** can access

the radio infrastructure **56** at a time; as a result, no performance gain may be realized by employing multiple remote network controllers **140** when only limited channels are available.

As illustrated in FIG. **28**, the local network **152** is used to connect the remote network controllers **140** together. The local network **152** may be, for example, an Ethernet local area network. Each of the remote network controllers **140** includes a subsystem synchronization process module **150** that is connected to the local network **152**. Two separate console interfaces **34'** may also be attached to the local network **152**. Each console interface **34'** may be attached to the local network **152** to allow an operator to configure and control a particular remote network controller **140**.

The subsystem synchronization process module **150** may be implemented through any combination of hardware and software and is responsible for keeping track of all routing tables and health and status information associated with both of the remote network controllers **140**. Each subsystem synchronization process module **150** is connected to an interprocess communications manager **28'** of one of the remote network controllers **140** and may access all routing tables and health and status information with respect to the remote network controller from the interprocess communications manager. The health and status information and routing tables may be periodically updated based on the status of and events present at the remote network controller **140**. The periodically updated health and status information and routing tables may then be shared with the other subsystem synchronization process module **150** via the local network **152** so that the tables and information associated with both of the remote network controllers **140** is maintained in each of the subsystem synchronization process modules **150**. Since the tables and information are periodically updated, a synchronization routine may be provided so that the information and tables are sent to the respective subsystem synchronization process modules **150** at predetermined intervals. If a particular subsystem synchronization process module **150** does not send or receive the tables and information, or if a particular subsystem synchronization process module **150** sends information indicating that one of the remote network controllers **140** has malfunctioned, the other subsystem synchronization process module **150** may reroute any existing connections to the host data controllers **22'** and to the wired network **10** of the malfunctioning remote network controller **140** to the remaining operational remote network controller **140**.

As further shown in FIG. **28**, the host data controllers **22'** have two ports, **154** and **156**, that are connected to a different remote network controller **140**. As in FIG. **52**, the remote network controller **140** communicates to the host data controller **22'** and sends health and status information through the ports. If the host data controller **22'** does not receive information that one of the remote network controllers **140** is operational, the host controller **22'** can switch ports, e.g., from port **154** to port **156**, in order to communicate with the other remote network controller **140**.

While the invention has been described with references to several exemplary embodiments, it is understood that the words which have been used herein are words of description and illustration, rather than words of limitation. Changes may be made, within the purview of the appended claims, without departing from the scope and spirit of the invention in its aspects.

For example, although FIG. **28** only shows two remote network controllers **140** that are connected by a local network **152**, it is possible to connect two or more remote network controllers by the local network **152** to provide increased redundancy. In addition, a plurality of local networks **152** may be provided to connect the remote network controllers. Other modifications to the present invention may include selectively processing inbound and outbound data in a different logic order and/or by different components. In accordance with such a modification, processing functions may be performed only by the control process, or in the interprocess communication manager. Another application may be combining the mobile interface with a host data controller, and placing the integrated unit within the remote network controller.

Referring now to FIG. **29**, therein is illustrated a general overview of another embodiment of the present invention which includes a mobile Router **200** in accordance with an aspect of the present invention. The Router **200** provides the mobile application or device **52** with the capability to selectively transmit and receive data over a plurality of radio frequency infrastructures **56** and/or the public switched telephone network **58** in accordance with user configured parameters.

Referring now to FIG. **30**, therein is illustrated a schematic block diagram of the mobile Router **200**. In the following description of the Router **200**, each of the elements will be initially generally described and in greater detail thereafter. As shown in FIG. **30**, the mobile application or device **52** may be attached to multiple Networks by the Router **200** through Network Interfaces **214**A–D, a Router Core **204**, and a Switch **212**. The Network Interfaces **214**A–D provide connectivity for data between the Switch **212** and the various Networks infrastructures (e.g., radio infrastructures **56** and public switch telephone network **58**) through which the mobile device or application **52** connects to the communications network **10** (see FIG. **1**). The Switch **212** is actuated by the Router Core **204**, and sends data to a fixed host application or device (e.g., RNC **20**) via the selected network. The Network Interface **214** provides information to the Network Availability process **210**, which sends this information to the Decision process **206**. The Decision process **206** operates in accordance with User Configured parameters **208** which specify when and through which Network the data is to be transmitted. The decision process **206** monitors the User Configuration parameters **208**, and the Network Availability **210**. When the Decision process **206** (in accordance with User Configuration **208** parameters) specifies that a Network (e.g., Network **3**) different than the Network currently in use (e.g., Network **1**) should be used, the Decision process **206** checks the Network Availability **210** for the particular Network to be switched to. If the Network is available, the Decision process **206** instructs the Router Core **204** to switch to the new Network. The Router Core **204** then updates routing tables (not shown) maintained within the Router Core **204** to reflect the new data path, and actuates the Switch **212** to connect to the new Network. Data may then flow over the new Network. In accordance with an aspect of the present invention, data may flow inbound to the fixed host through one Network, and outbound to the remote mobile Application or device **52** through the same Network, or through a different Network.

With reference to FIG. **30**, the mobile application or device **52** may comprise a software application running on a portable or laptop computer performing a variety of functions as programmed by the software application (e.g., database services). The Application or device **52** may also comprise a special purpose device designed to perform a particular function, such as a credit card reader or barcode

scanner. The Application or device **52** may generate a data stream which is sent to a fixed location (e.g., a host computer infrastructure **10**).

An exemplary application running on the mobile device **52** is a mobile remote client application which provides the remote user with the capability to send and retrieve data from a fixed database server application. The data may consist of customer records which, for example, may be used by service personnel operating a fleet of vehicles to service customers scattered about a wide geographic area. In the exemplary application, the mobile client application may request customer records from the fixed database server, and display the records for viewing by mobile service personnel. The mobile client application may send updated records to the fixed database as the service personnel finish assigned tasks. The updated records may contain a service history, equipment upgrades, and repairs for each customer.

Another exemplary application running on the mobile device **52** may be a client application which retrieves a list of dispatched jobs to be performed by the service personnel during each day. The jobs may be uploaded to the remote mobile device **52** each morning and stored in another client application in the mobile device **52**. As the service personnel change job locations, the status of each job may be updated to indicate a status, e.g., en route, arrived and finished with comments. The status may be sent from the application to the fixed home office, so a dispatcher at the home office is aware of the locations of service personnel in the field.

By way of non-limiting examples, the mobile device **52** may comprise a portable or laptop computer; a computer having an embedded Router **200**; a terminal or terminal emulator; a data gathering device (e.g., a SCADA system or remote telemetry system for obtaining data from a remote location for forwarding to a central location for processing); a card-swipe reader device (e.g., credit/debit/bank cards) for use in a mobile billing application, such as a taxi or mobile food cart; a smart-card reader; a logging device, such as those used in a package delivery system or fleet; a device for reading bar codes (e.g., for inventory control); and a remote application with data to send or to receive, from a fixed application or device (e.g., remote diagnostic tool). The above-noted applications are provided merely for exemplary purpose, and other applications and mobile devices **52** may be used with the Router **200** of the present invention.

Typically the device or Application **52** sends and receives data using a variety of protocols (e.g., Internet Protocol (IP)/transparent (via MDC **54**)/ack-nack, etc.). The use of a variety of protocols provides for open transport of data throughout many networks, and in particular, networks which support open standards such as IP. However, many proprietary networks which require interface and/or protocol translation remain in use. In the Router **200** of the present embodiment, the function of interfacing with networks and protocol translation may be performed by the Network Interfaces **214**A–D.

According to another aspect of the invention, other types of devices may be connected to the Network Interface **214**. Such devices may be used for functions other than data and voice communication. By way of non-limiting examples, these devices may include Global Positioning System (GPS) receivers and application processors.

The Router Core **204** is a function which shuttles messages between the Application or Device **52** and the various Networks. In accordance with the present embodiment, the router Core **204** may control which network of a plurality of usable network messages are to travel over, and connect access ports (described below) to each Network and the Application or Device **52**.

The Router Core **204** may also comprise a list of all possible "names" or "addresses" to which data may be sent, or from which data may be received. The local "names" or "addresses" of the Router Core **204** are stored in tables within a memory (not shown) of the Router Core **204**. Thus, the Router Core **204** may serve as a communications "address book" for the Router **200** of the present embodiment. The Router Core **204** also checks all messages passing through, and decides, based on the address and/or name entries in the tables, if the message is relevant to the attached Application or Device **52**, or to the fixed host (e.g., RNC **20**). The address of the fixed host may be stored in the Router Core table as well. In accordance with the table entries, received messages may be determined to be valid or invalid. The Router Core **204** may also actuate the Switch **212** in accordance with the output of the decision process **206**. The Switch **212** is actuated such that incoming and outgoing messages can be sent through the "current" network, as determined by the decision function **206** (to be described below).

The Switch **212** may comprise a message multiplexor, i.e., the Switch **212** performs a one-to-many function for in-bound messages (to the fixed hosts), and a "many-to-one" function for outbound messages (from the fixed host). As noted above, the appropriate network selection is made by the Router Core **204** in accordance with the output of the decision process **206**. Messages travel through the Switch **212**, the Router Core **204**, and the current Network Interface **214**.

Referring to FIG. **32**, the Switch **212** may be implemented using a combination of hardware (e.g., multiple electronic ports, one per Network Interface **214**) to perform the physical connection process **212**B, and software (e.g., handlers which are interrupted at each character to move the character to either the Router Core **204** (outbound), or to the current Network Interface **214** (in-bound)) to perform the switch logic process **212**A.

As a non-limiting exemplary hardware implementation, the Switch **212** may comprise an 80386EX microprocessor, running at 33 MHZ, 256 kilobytes of FLASH ROM, 512 kilobytes of static RAM, six asynchronous serial ports, two TTL-to-RS232 convertors interfacing with two of the six serial ports directly to compatible devices external to the Switch **212**, and four internal TTL serial interfaces to internally-mounted daughter boards, which carry Network Interfaces **214**A–D. Each Network Interface **214** mounted on a daughter board may include a power supply for the Network Interface, a serial interface to the 80386EX microprocessor, and an interface to the outside network. The outside network may be a radio, a LAN, an antenna (for internally-mounted radios in the Network Interface **214**), or other device accepting or supplying data from/to the Router **200**.

The Switching function of the Switch **212** is provided by each serial Network Interface port at the 80386EX microprocessor, and the software residing in FLASH ROM. The software logic determines which Network Interface to use for transmission and receipt of data. The decision is implemented in the Switch, by selecting a physical serial port (and therefore which Network Interface) is to be used as the current Network. The Decision software in the FLASH ROM instructs the microprocessor to send the data to a specific serial port (which is mapped to specific physical addresses within the address range of the 80386EX

microprocessor). The microprocessor then constructs the next message in the message buffers in RAM, and sends the message through the specific serial port which is designated as the "current Network" Interface port. The data then goes to the Network Interface (e.g., network interface **214**A) connected to that specific serial port and on to the Network infrastructure. Received data is input to the Network Interface (e.g., network interface **214**B which may be set to the "current Network" serial port) and the microprocessor, where the received data is processed by the microprocessor. In accordance with an aspect of the present invention, messages which are received through Network Interfaces which are not designated as the "current Network" are ignored.

The Network Interfaces **214**A–D are devices which present data to, or obtain data from the radio operating at the various R.F. Network frequencies, bandwidths, and modulations. The Network Interfaces **214**A–D may provide a port through which messages pass, to and from the Switch **212**. The messages are typically in the form of a sequence of serial digital bits. The Network Interfaces **214**A–D also may provide a modulator/demodulator function which transforms the digital data into an analog form which may be easily sent through the R.F. Network voicepath, based on characteristics of the assigned frequency band of the R.F. Network. The characteristics of analog transmissions are typically bandwidth (in Hertz, or cycles per second), noise present in the Network, and assigned frequency of the R.F. Network. Further, the Network Interfaces may interface with a radio, which may be included within the Network Interface **214**, or may be mounted externally to the Router **200** (as shown in FIG. **29**). The Network interface **214** radio interface comprises the actual physical connections to the radio for the voicepath data, the muting function (if present and/or required) and the functionality for issuing a Press-to-Talk to the radio, and for receiving the Transmit Grant signal from the radio; both are used for handshaking between the radio network and the Network Interface **214**. This handshaking may be necessary for proper timing of the data out onto the RF Network. The muting function is used for silencing received signals which represent data, rather than voice traffic, which enables a remote user to mute the audible noise of the data traffic, which can be annoying to the remote user.

Examples of Network Interface **214**A–D include the MDC **54** and the NovaTel Wireless NRM-6812 Cellular Digital Packet Data (CDPD) modem. Where the network interface **214** comprises the MDC **54**, the radio is mounted external to the MDC **54**, whereas in the NovaTel example, the radio and the network interface are integrated into a single unit.

As noted above, the Network Interfaces **214** provide connections to various types of networks. These networks may be wired (for example Public Switched Telephone Network **58**), or wireless (for example Cellular Digital Packet Data (CDPD)). The following non-limiting list includes networks that may be interfaced to the Router **200** by the Network Interfaces **214**A–D: private voice radio including conventional and trunked radios (e.g., using MDC **54**), Cellular Digital Packet Data (CDPD), Spread Spectrum (e.g., direct sequence and channel-hop), GSM, GPS receiver, satellite transponder, RDI (Ericsson) interface, AMPS, RAM Mobile (Mobitex), RS232, RS485, Angel (AT&T), Asynchronous Transfer Method (ATM), Integrated Services Digital Network (ISDN), public switched telephone network (PSTN (POTS) telephone network), Ethernet, Ardis, Personal Communications Services (PCS), and any other network which is either transparent or operates using a specific protocol.

The specific protocols to the above-listed networks are implemented in the Network Interfaces **214**A–D. These protocols may be very different, and therefore incompatible with each other. Additionally, a translation device may be provided in each Network Interface **214** to translate between IP and the particular network protocol. By providing such a translation device, the Application or Device **52** can use IP data regardless of the particular network the Application or Device **52** is actually using.

Referring to FIG. **31**, a description of the functional components of the Router **200** will now be described. The Router **20** may be implemented as an autonomous device with multiple connections to the networks through which data is to be routed. The user Configuration Interface **208** provides a means whereby an external device such as a keyboard/terminal may be used to supply configuration information such as preferred routes, network node addresses, etc. to the router. Such information is accepted by the Configuration Interface **208** and is placed into a non-volatile store (e.g., memory) which may be queried by other router components. In addition, capability may be provided whereby diagnostic information may be requested from the router and sent to the terminal device for evaluation by a technician.

The Router Core **204** is responsible for making all routing decisions. For a given destination network address specified within a data packet or datagram received from one of the network interface drivers **215**A–D, the most-preferred path will be selected and the data packet or datagram forwarded through the preferred network interface driver **215**A–D. Routing decisions are generally based upon such metrics as network speed and interface availability. Other metrics such as destination network, time of day, type of data, etc. may also be incorporated into the routing decision. Further, routing decisions may be made at the packet level such that each individual packet of data may be transmitted and/or received on different networks in accordance with the user configured parameters **208**.

Exemplary Network Drivers **215**A–D may include an Ethernet Driver, a Token-Ring Driver, and a Serial PPP Driver. The Ethernet Driver provides a means for sending and receiving data through an Ethernet-type network. The function of the driver is to shield the Router Core from the details of network media access. The Token-Ring Driver provides a means for sending and receiving data through a Token-Ring-type network. The function of the driver is to shield the Router Core from the details of network media access. The Serial PPP Driver provides a means for sending and receiving data through a PPP-based serial data link. The function of the driver is to shield the Router Core from the details of network media access. Other drivers **215**A–D may be provided to interface with other types of networks as necessary.

The Network Availability **210** (see also FIG. **30**) is a function which periodically interrogates each installed Network Interface **214** in the Router **200** and may determine if the Network Interface **214** is installed; if the Network Interface **214** is properly configured and functioning properly; if the Network Interface **214** is connected to the Network, on-line, and available for sending/receiving messages; and if the Network Interface **214** is in good health. The above interrogation process may be accomplished by monitoring a timer tick (provided by the switch microprocessor), which instructs the Network Availability **210** to query each Network Interface **214**. When the timer tick occurs, the Network Availability **210** function interrogates each Network Interface **214** as noted above. The status

of each Network Interface **214** is then passed to the Decision process **206**, which determines what the "next Network" will be if the result of the interrogation indicates that the "current Network" is experiencing transmission problems.

The Network Availability **210** of each Network Interface **214** is determined in a manner specific to the particular interfaced Network. For example, if the Network is CDPD, the Network Availability **210** interrogates the network to determine if the Network Interface **214** is currently registered with the Network, and therefore active. Also, in the CDPD network, the Network Availability **214** determines if the Received Signal Strength Indication (RSSI) is sufficient to transmit relatively error-free data. For example, in the NovaTel CDPD Network Interface a RSSI of −100 dBm will provide for good data transmission qualities. Thus, if the Network Availability **210** function queries the NovaTel CDPD Network Interface for the RSSI, and the response is −110 dBm, then the signal is too weak for error-free transmission, and therefore cannot be used at this time. This information is passed to the Decision process **206** to determine if the "current Network" should remain the "current Network", and if not, to determine what the "next Network" should be.

The User Configuration **208** block is used to define user configurable parameters by which the Router Core **204** selects the "current Network" and the "next Network". The Router parameters may include the date and time (e.g., yr-mo-da, hh:mm:ss), and the Network Interface **214** installed in each of the internal slots of the Router **200**. According to the present embodiment there are six internal slots to accommodate Network Interfaces to any of private voice radio using e.g., the MDC **54** and a variety of radios, both conventional and trunked; Cellular Digital Packet Data (CDPD), such as Sierra Wireless or NovaTel CDPD modems; spread spectrum, either direct sequence, or channel-hop, as Xetron Hummingbird spread spectrum modem; GSM, such as Ericsson serial GSM module; GPS receiver, such as Motorola VP Encore GPS receiver, or Trimble SVEE Six receiver; satellite transponder; RDI (e.g., Ericsson) interface, implemented via a software protocol module and quasi-RS232 interface to radio; AMPS; RAM Mobile (e.g., Mobitex); RS232 default and fixed for example in slots **1** and **2**; RS485; Angel (e.g., AT&T); ATM; ISDN; PSTN; Ethernet; Ardis; PCS; any other network which is either transparent or operates using a specific protocol; and none. Although six slots are disclosed herein, other numbers of slots may be provided.

Other user configurable parameters include: the priority of each internal slot, (e.g., **1** to **6**) where the slot with priority **1** is the default startup slot and Network; baud rate of each slot (a default rate may be set to 9600 bits per second, but may be configured to be any standard baud rate, divisible by 300, up to 115.2 kilo bits per second); cost per kilobyte per slot (e.g., $0.xx per kilobyte where the least costly slot that is available and highest priority will be default); protocol per slot (e.g., none, Point to Point (PPP), Serial Line Internet Protocol (SLIP), Hayes "AT" commands, transparent); slot mode, for example, transparent, PSTN, cellular, IP, receive only; slot name or address or phone number; slot to be used for diagnostics (e.g., default may be set to slot **2**); slot muting to be used (e.g., none, PL, DTMF, other); number of retry transmissions per Network Interface (per slot) before declaration of Network Interface failure (e.g, **0–10**); if slot Network Interface needs to be configured before it can operate (e.g., y,n); slot to be used for remote display (e.g., default may be set to slot **2**); slot to be used for Device or Application **52** (e.g., a connection to a mobile computer; default is slot **1**); and frequency at which Network Availability **210** is checked (e.g., default may be set to five seconds). Other user configurable parameters may be introduced and configured as necessary.

The User Configuration **208** function provides the user with the capability to instruct the Router **200** how to select a particular Network. These metrics may include, but are not limited to: which Network is connected to which Router port, time of day and date, priority (switching sequence) of each Network, cost per packet of each Network, and preferred default Network.

On power up, the User Configuration **208** is checked to determine if it is current. If the User Configuration **208** is determined to be out of date, the end user is requested to input a configuration. The user is notified by blinking LEDs on the front panel or by a message sent to the mobile device **52**. If the User Configuration **208** is determined to be current, no user input is requested.

Further, each Network is continuously evaluated for health and connectivity status. There are a number of parameters which are examined to determine this, including, but not limited to: Received Signal Strength Indication (RSSI), Clear to Send (CTS), Channel Clear/Channel Ready, and Transmit Grant.

The Decision process **206** continuously examines the User Configured parameters in the user configuration block **208**, to determine the next Network to use, in case the current Network becomes unavailable to send or receive data. Such an unavailability may arise because the remote user (and consequently the Router **200**) has moved beyond coverage of the Network, or because a problem has occurred with the current Network or the Network Interface **214**.

After the Decision process **206** has determined the next Network to use, the decision process **206** queries the Network Availability **210**. If the next Network is available, then the Decision process **206** updates the routing tables in the Router Core **204**. The Router Core **204** will then actuate the Switch **212** to physically connect the next Network as the current Network.

The Decision process **206** uses the User Configuration **208** parameters defined above to determine the specific criteria for each slot, to be used when deciding if the current Network is to remain the current Network, and if not, what the next Network shall be. Once the decision process **206** has made a tentative decision to switch to another Network (i.e., the next network is to become the current network), it checks the Network Availability **210** to ascertain if the Network is actually installed, configured, on-line, and in good health. For example, if the current Network is configured as priority #**3**, and the Network Availability **210** of the priority #**2** Network updates to, for example, "installed, configured, on-line, and in good health", then the priority #**2** Network becomes the next Network. The Decision process **206** will instruct the Switch **212** to switch the priority #**2** Network to the current network. Should the Decision process **206** decide to change Networks, it conveys an instruction to the Router Core **204** by instructing the Router Core **204** what the next Network Interface **214** is to be.

The process of the Decision process **206** checking the User Configuration **208** and the Network Availability **210** continues indefinitely, and is described in detail in FIGS. **33–36**. Generally, the process helps to guarantee that the mobile user always has access to a Network for sending and receiving data. This process also allows what is known now as "seamless roaming". This means that the mobile user can move between Networks and continue to have reliable data transmission on the different Networks.

FIGS. **33–36** illustrate the logic of the software in the router. Referring now to FIG. **33**, there is shown an exemplary initialization routine which builds the tables in the Router **200**. Upon initialization of the system, at Step **310** the first channel priority is checked. At Step **312**, it is determined whether or not the first channel is being examined. If it is the first channel, at Step **314**, table entries for the first channel are built. Information which is included in the table may be, e.g., IP address of the destination, intervening intermediate IP addresses, the assigned port, channel priorities, and the application being used. Typically channel one is assigned the highest priority. After the tables are built, the processing increments to the next channel at step **316**. From Step **316**, processing returns to Step **312**. If at Step **312** it is determined that the channel being checked is not the first channel, processing proceeds to Step **320** to query whether all channels have been checked. If all channels have not been checked, processing returns to Step **314** to continue building the table entries via steps **314** and **316** until all channels have been checked.

Once it has been determined that all channels have been checked, at Step **322** it is determined whether any tables have been built. If no tables have been built, at Step **324** a configuration error is recognized and the processing stops. Tables may not have been built previously, e.g., if there are problems with the IP address, i.e., there was no destination address. If at Step **322** it is determined tables were already built, processing proceeds to Step **326** where all channels are initialized and data transportation begins via the first channel.

From Step **326** the processing proceeds to Step **328**, also shown in FIG. **35**, which illustrates an exemplary flow diagram of the Router **200** logic for accounting the Network Availability **210** (FIG. **30**) and User Configuration **208** (FIG. **30**) to decide which channels to use for data transport. Beginning at Step **328**, processing proceeds to Step **330** where the channel is set to the current channel in a database which is described in more detail below. From there, processing proceeds to Step **332** to retrieve the next channel to switch to from the database. The database is stored in flash memory and contains configuration information for each channel including how each channel is set up in the Router **200** and what configuration values are for each Network Interface **214**A–D. In addition, the database stores which channel is current and the history of previous current channels. The tables discussed with reference to FIG. **33** at Step **314** are also stored in the database.

At step **334** a determination is made as to whether the previous channel is available. Of course if this is the first time through, no previous channel will exist. If the previous channel is not available, at Step **336** a determination is made as to whether the next channel is available. If the next channel is available, at Step **338** a determination is made as to whether or not the priority is lower and it is time to switch. The determination is made by looking at the information in the User Configuration **208** (FIG. **30**). If it is time to switch, at Step **340** a switch to the next channel is made. From there, processing continues to step **341**, where it is determined if the channel was switched. If the channel was switched, processing continues to step **343** where a ping is sent to confirm the path is available. From step **343**, the processing continues to Step **342**, also shown in FIG. **34**. If, at step **341**, it is determined the channel was not switched, processing continues to step **342**.

Returning to Step **334**, if it is determined that a previous channel is available, at Step **344** an inquiry is made as to whether or not the previous channel has a higher priority and it is time to switch. The determination is made by consulting the information in the User Configuration **208** (FIG. **30**). If it is determined the previous channel is a higher priority and it is time to switch, at Step **346** a switch to the previous channel is made. From Step **346**, the processing proceeds to Step **341** as previously described.

If at Step **344** it is determined that it is not time to switch and the priority is not higher, processing proceeds to Step **336** where it is determined whether the next channel is available. If the next channel is not available, at Step **348** the current channel is not switched and the processing proceeds to Step **341** as described above. If at Step **336** the next channel is available, then at Step **338** the inquiry into priority and time to switch is made as previously described. At Step **338**, if it is not time to switch and the priority of the next channel is not lower, the Router **200** stays on the current channel at Step **348**.

Refer now to FIG. **34** which illustrates a flow chart of exemplary logic for checking the availability of each network interface. Starting at Step **342** processing proceeds to Step **344** where the status of the channel being used is recorded in the database. Furthermore, at Step **344**, the Router **200** front panel LED's are updated. If at Step **346** it is determined the availability of all channels has not been checked, at Step **348** the next channel is identified and at Step **350** the next channel's availability is polled. A channel is not available if it is being used for a mobile device **52** i.e. the channel is already one end of the network. If the channel is not available, the processing returns to step **348**. If the channel is determined to be available at step **350**, processing proceeds to Step **328** also shown in FIG. **35**.

If at Step **346** it is determined that the availability of all channels has been checked, at Step **352** the availability of the present channel is determined. If the present channel is available, a connection is made at Step **354**. If the present channel is not available, processing proceeds to Step **356** for error handling. The error handling procedure is discussed with reference to FIG. **36** below. Upon completion of the error handling procedure, at Step **360** the channel is set equal to one at Step **362**. At Step **350**, the procedure continues as previously described.

Referring now to FIG. **36**, which is an exemplary flow diagram of the Router, **200** error handling logic, Step **356** continues from FIG. **34**. At Step **370**, the present channel is deemed to be non-available. At Step **372**, the next and previous channels are also confirmed to be non-available. At Step **374** an error is indicated to the device or application. At Step **376** an availability routine is run such as that described previously. From the availability routine at Step **36**, the processing continues to Step **360** as discussed with reference to FIG. **34**.

The Router **200** of the present invention may be used inside a mobile vehicle, or carried by a person in a portable application. Further, the Router **200** may be provided as an external component connected to a portable device (e.g., a laptop computer) or may be implemented within the portable device, such that the portable device and the Router **200** are provided as one integrated unit. Further, the Router **200** may be used in conjunction with, or integrated into measuring and testing equipment, and transmission equipment. Such a remote device may be needed for very remote monitoring applications, such as wildlife studies, etc., necessitating the use of multiple Networks.

Referring now to FIG. **37**, there is shown the software architecture **219** of the Router **200** in accordance with an embodiment of the present invention. The architecture is

strictly layered in that data flows only vertically between adjacent layers. The definition of each layer will now be described.

The Application layer consists of various processes that perform services directly related to the function(s) for which the device is defined. This includes such services as defining a device configuration, making decisions about which route to select for the transport of data and performing various diagnostic functions.

The Presentation layer consists of a protocol-independent insulating layer between the applications and the lower-level networking functions. The Presentation layer implements a Berkley sockets compliant application programming interface (API).

The Networking layer performs all processing related to handling the Internet Protocol (IP). The main function of the networking layer in this environment is the routing of data passed into the layer from either above or below back out through selected Network Interfaces to deliver that data to the intended destination. The relationship of destination and network interface is maintained by the Configuration Module and Routing Decision Module applications.

The Data-Link layer provides logical Network Interfaces through which the Networking Layer may send and receive data. One or more of these Network Interfaces may be active at any time. At least one network interface must be active for the device to function properly. The main purpose of the Data-Link layer is to insulate the Networking layer from the details of the many link-level protocols used to transport data.

The Device-Specific layer deals with the details of establishing and maintaining data communications through various types of communication devices such as radios, modems and data controllers. Each Device-Specific driver handles the vagaries of configuring and interfacing with various types of communication devices while presenting a uniform interface to the Data-Link layer.

The Physical Interface layer handles the direct interface to external components. For example: A serial port driver may handle the sending and receiving of individual data bytes through a specific type of serial controller such as an Intel 8250.

A description of the functionality supported by various module blocks as presented in FIG. **37** will now be described.

The Configuration Module **222** is an Application layer module that allows a technician to maintain a database of device configuration information. A technician may access the Configuration Module via a diagnostic serial port. Another implementation may allow a technician to access the Configuration module through any of the defined Network Interfaces via a standard socket.

The Routing Decision Module **220** selects the preferred network interface through which outbound data is transmitted. This decision is based upon a variety of metrics including: Interface availability; Time of day; Type of service required; Interface priority and others. Examples of various routing metric schemes are presented later.

The TCP/IP Socket Interface **224** supports an Application Programming Interface (API) which, for example, conforms to the standard Berkley sockets paradigm. Its purpose is to shield the Application Layer from the details of the underlying networking protocols. It allows different network implementations to be employed without the applications being required to adapt.

The TCP/IP Router/Gateway **226** implements standard IP host support with the additional capability of being able to act as a gateway between multiple networks. IP datagrams received by this layer that are not destined for a local IP host address are forwarded through the network interface that is currently designated as the preferred route for the given destination address. It is possible that the management and selection of preferred routes is implemented by the Routing Decision Module **220** in the Application layer.

The PPP Protocol Driver **228** provides a network interface whose data-link protocol conforms to the Point-To-Point protocol standard. The SLIP Protocol Driver **230** provides a network interface whose data-link protocol conforms to the Serial-Line Internet Protocol de facto standard. Other protocol drivers **230** may be implemented which provide Network Interfaces which support either existing protocols or future protocols. The intent is to convey that the underlying link-layer protocol is transparent to the upper and lower layers and that additional protocols may be easily supported.

The MDC Interface Driver **234** provides device-specific support for Mobile Data Controller **54**, as described above. The CDPD Interface Driver **236** provides device-specific support for a Cellular Digital Packet Data controller. Other device-specific drivers, e.g., Modem "X" Interface Driver **238** may be implemented to support current or future devices.

The Serial Port Driver **240** deals with the hardware aspects of asynchronous serial data communications such as manipulating a Serial I/O controller or other such external interface. Other physical layer drivers **242** may be implemented which support different external interface devices either existing or in the future.

Although the invention has been described herein with reference to particular means, materials and embodiments, the invention is not intended to be limited to the particulars disclosed herein; rather, the invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims.

For example, the router of the present invention may be included as an internal component of the mobile device, proving for an integrated mobile device. Optionally, the router may be implemented entirely as a software process running on, for example, a portable personal computer. In such an implemention, the internal slot(s) of the personal computer may be provided with network interface(s) and a software program may serve as the router core. Further, data may be routed to the different networks at another level than at the packet level. For example, entire messages may be routed over various networks if such a configuration is required.

What is claimed is:

1. A method for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the method comprising:

maintaining a priority of each wireless network, the priorities indicating a most preferred path;

determining availability of each wireless network based upon status information associated with each wireless network;

indicating a current most preferred network from the wireless networks determined to be available, the indication being based upon the network priorities;

switching from a current network, which is dissimilar from the current most preferred network, to the current most preferred network during a transmission, at least one of the current network and current most preferred network being time continuous; and

remaining connected to the current network for a period of time after switching to the current most preferred network.

2. The method of claim **1**, in which the multiple wireless networks are simultaneously in coverage.

3. The method of claim **1**, further comprising defining priorities based upon user defined criteria.

4. The method of claim **1**, in which the switching further comprises switching to a higher priority network when the higher priority network becomes available.

5. The method of claim **1**, in which the switching further comprises not switching to a lower priority network when a higher priority network is available.

6. The method of claim **1**, further comprising dynamically modifying the priority of each wireless network.

7. The method of claim **1**, in which the selecting further comprises selecting based upon information in addition to the network priorities.

8. The method of claim **7**, in which the information comprises cost for each transmission.

9. The method of claim **1**, in which the determining availability further comprises determining if a previous network is available; and

the selecting further comprises selecting the previous network as the current most preferred network when the previous network is available and the previous network is a higher priority than a current network.

10. The method of claim **9**, in which the determining availability further comprises determining if a next network is available when the previous network is not available; and

the selecting further comprises selecting the next network as the current most preferred network when the next network is available and the next network is a higher priority than the current network.

11. The method of claim **10**, in which the determining availability further comprises determining if a next network is available when the previous network is a lower priority than the current network; and

the selecting further comprises selecting the next network as the current most preferred network when the next network is available and the next network is a higher priority than the current network.

12. A method for transmitting data from a local device through a plurality of dissimilar parallel wireless networks, at least two of the networks having different transmission formats, the method comprising:

receiving data from the local device in a first format;

selecting a first network from the plurality of wireless networks;

switching to the first wireless network;

converting the received data from the first format to a second format that is required by the selected first wireless network;

transmitting the converted data through the selected first wireless network;

restoring the data to the first format after transmission through the first wireless network occurs;

selecting a second network from the plurality of wireless networks, the second network being dissimilar from the first network;

switching to the second network; and

transmitting the data received in the first format through the selected second wireless network;

wherein a transmission occurs from the local device while switching from the first wireless network to the second wireless network and/or while switching from the second wireless network to the first wireless network;

and wherein after switching networks the local device remains connected to both the first network and the second network for a period of time.

13. The method of claim **12**, further comprising:

converting the data received from the first format to a third format required by the selected second wireless network, after switching to the second network;

wherein the transmitting of the data received in the first format further comprises transmitting the data converted to the third format through the selected second wireless network and restoring the data to the first format after the transmission through the second wireless network occurs.

14. The method of claim **13**, in which the second format comprises an IP based format and the third format comprises a non-IP based format.

15. The method of claim **13**, in which the second format comprises a non-IP based format and the third format comprises another non-IP based format that is dissimilar from the second format.

16. The method of claim **13**, in which the second format comprises an IP based format and the third format comprises another IP based format that is dissimilar from the second format.

17. A computer readable medium storing a program for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the medium comprising:

a priority code segment that maintains a priority of each wireless network, the priorities indicating a most preferred path;

an availability code segment that determines availability of each wireless network based upon status information associated with each wireless network;

an indicating code segment that indicates a current most preferred network from the wireless networks determined to be available, the indication being based upon the network priorities;

a switching code segment that switches from a current network, which is dissimilar at a link layer from the current most preferred network, to the current most preferred network during a transmission while remaining connected to the current network for a period of time after switching to the current most preferred network.

18. The medium of claim **17**, further comprising a defining code segment that defines priorities based upon user defined criteria.

19. The medium of claim **17**, further comprising a modifying code segment that dynamically modifies the priority of each wireless network.

20. The medium of claim **17**, in which the selecting code segment further selects based upon information in addition to the network priorities.

21. The medium of claim **20**, in which the information comprises cost for each transmission.

22. The medium of claim **17**, in which the availability code segment further comprises determining if a previous network is available; and

the selecting code segment further comprises selecting the previous network as the current most preferred network when the previous network is available and the previous network is a higher priority than a current network.

23. The medium of claim **22**, in which the availability code segment further comprises determining if a next network is available when the previous network is not available; and

the selecting code segment further comprises selecting the next network as the current most preferred network when the next network is available and the next network is a higher priority than the current network.

24. The medium of claim **23**, in which the availability code segment further comprises determining if a next network is available when the previous network is a lower priority than the current network; and

the selecting code segment further comprises selecting the next network as the current most preferred network when the next network is available and the next network is a higher priority than the current network.

25. A computer readable medium storing a program for transmitting data from a local device through a plurality of dissimilar parallel wireless networks, at least two of the networks having different transmission formats, the medium comprising:

a receiving code segment that receives data from the local device in a first format;

a first selecting code segment that selects a first network from the plurality of wireless networks;

a first switching code segment that switches to the first wireless network;

a first converting code segment that converts the received data from the first format to a second format that is required by the selected first wireless network;

a first transmitting code segment that transmits the converted data through the selected first wireless network;

a first restoring code segment that restores the data to the first format after transmission through the first wireless network occurs;

a second selecting code segment that selects a second network from the plurality of wireless networks, the second network being dissimilar from the first network;

a second switching code segment that switches to the second network; and

a second transmitting code segment that transmits the data received in the first format through the selected second wireless network;

wherein a transmission occurs from the local device while switching from the first wireless network to the second wireless network and/or while switching from the second wireless network to the first wireless network, and

wherein after switching networks the local device remains connected to both the first network and the second network for a period of time.

26. The medium of claim **25**, further comprising:

a second converting code segment that converts the data received from the first format to a third format required by the selected second wireless network, after switching to the second network;

wherein the second transmitting code segment further comprises transmitting the data converted to the third format through the selected second wireless network and a second restoring code segment that restores the data to the first format after the transmission through the second wireless network occurs.

27. The medium of claim **26**, in which the second format comprises an IP based format and the third format comprises a non-IP based format.

28. The medium of claim **26**, in which the second format comprises a non-IP based format and the third format comprises another non-IP based format that is dissimilar from the second format.

29. The medium of claim **26**, in which the second format comprises an IP based format and the third format comprises another IP based format that is dissimilar from the second format.

30. A router for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the router comprising:

a priority system that maintains a priority of each wireless network, the priorities indicating a most preferred path;

a plurality of transmitters, each transmitter operating with one of the wireless networks:

a determining system that determines availability of each wireless network based upon status information associated with each wireless network;

an indicator that indicates a current most preferred network from the wireless networks determined to be available, the indication being based upon the network priorities; and

a switch that switches from a current network, which is dissimilar from the current most preferred network, to the current most preferred network during a transmission while remaining connected to the current network for a period of time after switching to the current most preferred network.

31. The router of claim **30**, further comprising a modification system that dynamically modifies the priority of each wireless network.

32. The router of claim **30**, in which the selector selects based upon information in addition to the network priorities.

33. The router of claim **32**, in which the information comprises cost for each transmission.

34. A router for transmitting data from a local device through a plurality of dissimilar parallel wireless networks, at least two of the networks having different transmission formats, the router comprising:

a receiver that receives data from the local device in a first format;

a first selector that selects a first network from the plurality of wireless networks;

a first switch that switches to the first wireless network;

a first converter that converts the received data from the first format to a second format that is required by the selected first wireless network;

a first transmitter that transmits the converted data through the selected first wireless network;

a first restoring system that restores the data to the first format after transmission through the first wireless network occurs;

a second selector that selects a second network from the plurality of wireless networks, the second network being dissimilar from the first network;

a second switch that switches to the second network; and

a second transmitter that transmits the data received in the first format through the selected second wireless network;

wherein a transmission occurs from the local device while switching from the first wireless network to the second wireless network and/or while switching from the second wireless network to the first wireless network, and

wherein after switching networks the local device remains connected to both the first network and the second network for a period of time.

35. The router of claim **34**, further comprising:

a second converter that converts the data received from the first format to a third format required by the selected second wireless network, after switching to the second network;

wherein the second transmitter transmits the data converted to the third format through the selected second wireless network and

the router further comprises a second restoring system that restores the data to the first format after the transmission through the second wireless network occurs.

36. The router of claim **35**, in which the second format comprises an IP based format and the third format comprises a non-IP based format.

37. The router of claim **35**, in which the second format comprises a non-IP based format and the third format comprises another non-IP based format that is dissimilar from the second format.

38. The router of claim **35**, in which the second format comprises an IP based format and the third format comprises another IP based format that is dissimilar from the second format.

39. A computer readable medium storing a program for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the medium comprising:

an availability code segment that ascertains availability of at least two of the wireless networks based upon the status information;

a determining code segment that determines whether to switch between networks when at least two networks are available, in response to a user configuration and each network's speed; and

a switching code segment that switches from a first available network to a second available network, which is dissimilar at a link layer from the first available network, during a transmission while remaining connected to both the first network and the second network for a period of time.

40. The medium of claim **39**, in which the availability code segment further comprises a pinging code segment that pings at least two of the wireless networks.

41. The medium of claim **39**, in which the status information comprises a received signal strength of each wireless network.

42. The medium of claim **39**, in which the switching occurs when the second network is faster than the first network.

43. The medium of claim **39**, in which the switching occurs when the second network has a higher priority than the first network.

44. The medium of claim **39**, further comprising a packet size code segment that determines a packet size prior to transmitting data.

45. The medium of claim **39**, in which one of the dissimilar networks comprises a CDPD network.

46. The medium of claim **39**, in which one of the dissimilar networks comprises a GSM network.

47. The medium of claim **39**, in which one of the dissimilar networks comprises a EDACS network.

48. The medium of claim **39**, in which one of the dissimilar networks comprises a satellite network.

49. The medium of claim **39**, in which the availability code segment further comprises periodically checking the status of the networks.

50. A method for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the method comprising:

ascertaining availability of at least two of the wireless networks based upon the status information;

determining whether to switch between networks when at least two networks are available, in response to a user configuration and each network's speed;

switching from a first available network to a second available network during a transmission, the second network being dissimilar from the first network;

stopping transmitting over the first available network after switching to the second available network; and

remaining connected to the first network for a period of time after switching to the second network.

51. A computer readable medium storing a program for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the medium comprising:

an availability code segment that determines availability of at least two of the wireless networks;

an identifying code segment that identifies a current most preferred network from the wireless networks determined to be available, the identification being based upon a type of data being transmitted; and

a switching code segment that switches from a current network, which is dissimilar from the current most preferred network, to the current most preferred network during a transmission and remains connected to the current network for a period of time after switching.

52. The medium of claim **51** in which the availability code segment further comprises a pinging code segment that pings at least two of the wireless networks.

53. The medium of claim **51** in which the status information comprises a received signal strength of each wireless network.

54. The medium of claim **51**, in which the availability code segment further comprises periodically checking the status of the networks.

55. The medium of claim **51**, in which the switching occurs when the current most preferred network has a higher priority than the current network.

56. The medium of claim **51**, further comprising a packet sizing code segment that determines a packet size prior to transmitting data.

57. The medium of claim **51**, in which one of the dissimilar networks comprises a CDPD network.

58. The medium of claim **51**, in which one of the dissimilar networks comprises a GSM network.

59. The medium of claim **51**, in which one of the dissimilar networks comprises a EDACS network.

60. The medium of claim **51**, in which one of the dissimilar networks comprises a satellite network.

61. A method for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the method comprising:

determining availability of at least two of the wireless networks;

identifying a current most preferred network from the wireless networks determined to be available, the identification being based upon a type of data being transmitted;

switching from a current network, which is dissimilar from the current most preferred network, to the current most preferred network during a transmission; and

remaining connected to the current network for a period of time after switching to the current most preferred network.

62. A method for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the method comprising:

determining availability of at least two of the wireless networks;

identifying a current most preferred network, when multiple wireless networks are determined to be available, the identification being based upon a speed of each available network; and

switching from a current network, which is dissimilar at a link layer from the current most preferred network, to the current most preferred network during a transmission; and

remaining connected to the current network for a period of time after switching to the current most preferred network.

63. The method of claim **62**, further comprising determining a packet size prior to transmitting data.

64. The method of claim **62**, in which one of the dissimilar networks comprises a CDPD network.

65. The method of claim **62**, in which one of the dissimilar networks comprises a GSM network.

66. The method of claim **62**, in which one of the dissimilar networks comprises a EDACS network.

67. The method of claim **62**, in which one of the dissimilar networks comprises a satellite network.

68. A mobile system, comprising:

a local device comprising a database server application, the local device residing on a local area network;

a server connected to the local device via the local area network, the server being connected to a plurality of incompatible wireless networks; and

a mobile device connected to the plurality of incompatible wireless networks, the mobile device being associated with a plurality of transmitters, each transmitter operating with one of the dissimilar networks, the mobile device comprising a client application that enables a remote user to send and retrieve data from the database server application via the server, the mobile device sending data to the database server application via at least two of the plurality of incompatible wireless networks while switching between the at least two incompatible wireless networks, and remaining connected to the at least two incompatible wireless networks for a period of time after switching.

69. A mobile system, comprising:

a local device residing on a local area network, the local device storing a list of jobs to be performed by field service personnel;

a server connected to the local device via the local area network, the server being connected to a plurality of incompatible wireless networks; and

a mobile device connected to the plurality of incompatible wireless networks, the mobile device comprising a client application that retrieves the list of jobs to be performed by field service personnel, and that updates ajob status, the updated job status being sent to the local device via the server to inform a dispatcher of locations of field service personnel, the updated status being transmitted via at least two of the plurality of incompatible wireless networks while switching between the at least two incompatible wireless networks, and remaining connected to the at least two incompatible wireless networks for a period of time after switching.

70. A computer readable medium storing a program that enables switching between a plurality of incompatible wireless networks connected between a server and a mobile device, the server being connected to a local device via a local area network, comprising:

a transmitting code segment that transmits an updated job status via the server to the local device to inform a dispatcher of locations of field service personnel, the updated status being transmitted via at least two of the plurality of incompatible wireless networks while switching between the at least two incompatible wireless networks, and remaining connected to the at least two incompatible wireless networks for a period of time after switching, the job status being updated by an application that also retrieves a list of jobs to be performed by field service personnel from the local device.

71. A method for dynamically routing data over multiple dissimilar parallel wireless networks that are each monitored for status information, the multiple wireless networks being simultaneously in coverage, each wireless network being associated with a transmitter, the method comprising:

maintaining a priority of each wireless network, the priorities indicating a most preferred network;

determining availability of each wireless network based upon status information associated with each wireless network, including determining if a previous network is available, and determining if a next network is available when the previous network is not available or is a lower priority than a current network;

indicating a current most preferred network from the wireless networks determined to be available, the indication being based upon the network priorities, the current most preferred network comprising the previous network when the previous network is available and the previous network is a higher priority than the current network, which is dissimilar at the link layer from the current most preferred network;

switching from the current network to the current most preferred network, which has a higher priority, during a transmission when the higher priority network becomes available;

interrupting transmitting over the current network after switching to the current most preferred network; and

remaining connected to the current network for a period of time after switching to the current most preferred network.

72. A computer readable medium storing a program that enables switching between a plurality of dissimilar wireless networks, at least one of the dissimilar networks comprising a GSM network connected between a server and a mobile device, the server being connected to a local device via a local area network, comprising:

an availability code segment that periodically checks the status of the dissimilar networks, including the GSM network; and

a transmitting code segment that transmits an updated job status via the server to the local device to inform a dispatcher of locations of field service personnel, the updated status being transmitted via at least two of the plurality of dissimilar networks while switching between the at least two dissimilar networks when a second of the dissimilar networks is faster than a first of the dissimilar networks and when the second network has a higher priority than the first network, and remaining connected to the at least two dissimilar networks for a period of time after switching, the job status being updated by an application that also retrieves a list of jobs to be performed by field service personnel from the local device.

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